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INTRODUCING THE ASPRS SMARTPHONE APP

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The American Society for Photogrammetry and Remote Sensing (ASPRS) has launched an association and conference focused smartphone app for use by ASPRS members and those interested in the Society. The app keeps ASPRS competitive and continues to provide members with the tools they find essential, such as real-time access to association news, member directories, information on ASPRS webinars and conferences, and critical industry alerts all from their iPhone or Android smartphone. The app is available on both iPhone and Android platforms.

Now everyone can have the association experience right at their fingertips. The technology available through the smartphone app includes accessing the ASPRS mobile website, direct access to "My ASPRS" portals with editing and log-in capability, a student information tab with focused activities and information, publications tab for browsing the ASPRS Bookstore and online publications, an upcoming webinar and events calendar and membership "Join Now" material.

In addition, the ASPRS smartphone app includes a second screen dedicated to conference activities. The latest conference information is uploaded to the app about a month prior to the upcoming conference and then requires the well-known "shake to update" for the latest app information.

The Conference side of the app allows attendees to connect with the conference web page, access a dynamic electronic final program, create a personalized calendar of events during the conference week, view a map of activities, restaurants and attractions surrounding the conference location, post personal experiences and leave live real-time comments for other attendees on the "Fan Wall", a "Socialize" tab for access to ASPRS social media pages, and an "FAQ" tab with the most important questions and answers asked during the conference.

ASPRS is continuously working to improve communications with our members and stakeholders, and expanding the mobile app beyond its initial conference-focused purpose in order to address a wider range of ASPRS programs and information sources was a natural transition.

Downloading the new ASPRS app is simple! iPhone users can visit the Apple App Store and download the ASPRS App free of charge. Android users may access via the Google Plays Store to download the new version, also free of charge. Individuals may also find the links to download the smartphone app on the ASPRS website. Download the ASPRS App today!

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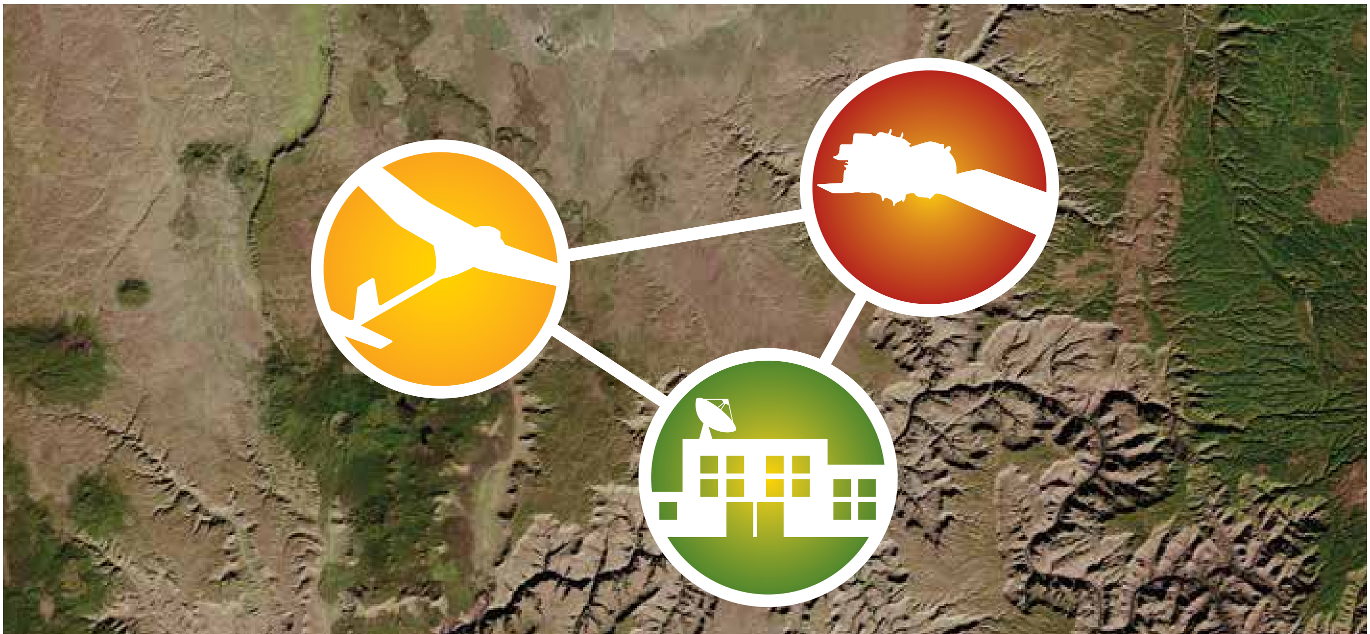

PECORA 19

Sustaining Land Imaging...
UAS to Satellites

in conjunction with the Joint Symposium of ISPRS Technical Commission I and IAG Commission 4

November 17-20

2014

Renaissance
Denver Hotel

Denver, Colorado

The 19th William T. Pecora Memorial Remote Sensing Symposium – Sustaining Land Imaging: UAS to Satellites will be held in conjunction with the Joint Symposium of the International Society for Photogrammetry and Remote Sensing (ISPRS) Technical Commission I and International Association of Geodesy (IAG) Commission 4. The Pecora 19 Symposium will be held November 17-20, 2014 at the Renaissance Denver Hotel, Denver, Colorado and will be combining various general sessions and special technical sessions throughout the week with the ISPRS/IAG Symposium.

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PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

The official journal for imaging and geospatial information science and technology

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COLUMNS

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DEPARTMENTS

The cover image was taken by Valley Air Photos on August 16, 2012. Valley Air Photos was contracted by Access Geographic of Tempe, Arizona to support a RFP awarded by the Lower Elwha Klallam Tribe and the City of Port Angeles, Washington for orthophotography and contour mapping. This color infrared image is of the Port Angeles Coast Guard Air Station and was collected with the Vexcel Ultracam X digital camera at a 3cm resolution. The geospatial information collected was used for watershed drainage and sea cliff erosion assessment, both critical issues along the Olympic Peninsula of Washington. The resulting images from this flight showcased the incredible detail and accuracy that Valley Air Photos achieves with the Ultracam X digital camera. Valley Air Photos is an aerial acquisition company based in Caldwell, ID. They have been providing quality, high accuracy, aerial photography for over 28 years. With an office in Caldwell, Idaho and Glendale, Arizona, Valley Air Photos serves clients across the US and Canada. For more information on Valley Air Photos and its services email: kevin@valleyairphotos.com or visit: www.valleyairphotos.com.

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PEER-REVIEWED ARTICLES

LETTER FROM THE EXECUTIVE DIRECTOR

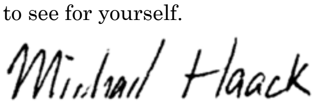
Why do you go to the ASPRS annual meeting? Is it to hear the talks? Maybe to give a technical presentation. Perhaps to see the exhibits. Or to roll out a new product. Some go to meet up with old friends, while others go to make new connections. Are you looking for a job? Or maybe you are an employer looking to hire. Do you go to evaluate potential acquisitions or negotiate contracts and close a deal? In each case there is the intersection of a market with a need, and that intersection occurs this year in Louisville.

Here is why I go to the ASPRS annual meeting – it's because of the ***exotic locations***! No, really, have you been to Louisville before? If not, you've been missing out. Did you know that Louisville is the home of the world's only full underground zipline and ropes challenge course? Check out the Louisville Mega Cavern, a man-made cave beneath the streets that is rich in history, geology, mining, recycling, and green building technology. (Hmm... how people navigate under there?) Are you a fan of great American heroes? Then check out the Muhammad Ali Center, which features an interactive museum to inspire people to pursue greatness in their own lives, communities and countries. If it's a different type of slugging you enjoy (baseball, not boxing!), then visit the Louisville Slugger Museum and Bat Factory. ASPRS has been around almost 80 years, but these bat makers have been around for 125! And you get a free mini-bat with every tour. You could take a stroll along the "Urban Bourbon Trail" Not to mention the "unforgettable" Evan Williams Bourbon "experience". True, Louisville is not Honolulu, but it's a lot more convenient for most, it is reasonably priced, and you'll be so busy socializing and technologicalizing that there wouldn't be time for surfing even if you could. (Don't worry, dude, can still surf the internet in Louisville.) Kidding aside, discover Louisville – you might be pleasantly surprised.

Now for the real reason I go to the ASPRS annual conference – it is to keep current with emerging technologies and the people who create them. The theme this year is "geospatial power in our pockets." As you know, there is a mobile revolution going on. Sensors, geospatial systems, and intelligent maps and images are in the midst of it as key enablers. There is huge market opportunity for our members, whether they are academic researchers in search of practical application, government or industry end users seeking to employ new capabilities, or technology providers on the forefront of innovation looking for buyers. Speaking of power in our pockets, did you know that ASPRS has its own mobile app? You can download it for free from the Apple Apps Store and Google Play for Android. I will be using it as a guide to the conference.

Interested in some highlights of the conference? I could tell about the NGA unclassified session, but then I'd have to kill you (just kidding – it's unclassified). I really could tell you about the LiDAR and UAS talks, but I'd rather you hear them for yourself. I know of at least one new product rollout happening in Louisville, and I expect there will be others. And, we're excited to be able to link with the JACIE workshop, which brings together commercial imagery and government applications. You can pay a single registration fee for both events which are being held back-to-back, thus saving travel costs and time out of the office.

ASPRS staff have been working really hard to refresh, renew, and modernize the conference, create more opportunities for networking, and fill the exhibit hall with activity. Our members have been upping their technical game, and former members are rejoining. Times, they are a changin'. Join us to see for yourself.



Dr. Michael Hauck, ASPRS Executive Director

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

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ASPRS Research on Quantifying the Geometric Quality of Lidar Data

Aparajithan Sampath[1], Hans K. Heidemann[2], Gregory L. Stensaas[3], Jon B. Christopherson[4]

The American Society for Photogrammetry and Remote Sensing's Lidar Cal/Val (calibration/validation) Working Group led by the US Geological Survey (USGS) to establish "Guidelines on Geometric Accuracy and Quality of Lidar Data" has made excellent progress via regular teleconferences and meetings. The group is focused on identifying data quality metrics and establishing a set of guidelines for quantifying the quality of lidar data. The working group has defined and agreed on lidar Data Quality Measures (DQMs) to be used for this purpose. The DQMs are envisaged as the first ever consistent way of checking lidar data. It is expected that these metrics will be used as standard methods for quantifying the geometric quality of lidar data. The goal of this article is to communicate these developments to readers and the larger geospatial community and invite them to participate in the process.

Introduction and Background

Lidar data are well on their way to becoming as important as photogrammetric imagery to geospatial analysis. However, the standards of Quality Assurance and Control (QA and QC) that transform photogrammetric imagery from a mere photograph to a metric tool are not as developed for lidar data. The current lidar data quality assessment methods are not adequate in the reporting of a) the quality of calibration of lidar system, which is an essential indicator of the overall quality of data, and b) the horizontal accuracy of the data. Recognizing this, the USGS has partnered with the ASPRS Lidar Division and the Airborne Lidar Committee to form a Calibration/Validation (Cal/Val) Working Group with a goal to promote industry-accepted guidelines and tools to help assess the quality of lidar data. The Cal/Val Working Group consists of representatives from the Government (e.g. USGS, National Geodetic Survey, National Geospatial Intelligence Agency, etc.), the industry (lidar instrument manufacturers, data providers/vendors, software developers) and academia. This paper discusses the Cal/Val Working Group's research efforts and their current status.

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The Working Group is synthesizing these efforts into a draft best practices/guidelines document (titled Guidelines on Geometric Accuracy and Quality of Lidar Data) for QA/QC processes. These efforts broadly fall under the following steps:

- Defining procedures for measuring the inter-swath goodness of fit. These procedures include defining three Data Quality Measures (DQMs)
- Suggesting the use of targets and Ground Control Points (GCPs) on natural surfaces of all slopes to measure the absolute accuracy
- Suggesting the use of sensor model based rigorous lidar system calibration methods.

These steps are encapsulated in the framework shown in Figure 1. The framework is designed such that the processes for measuring the accuracy (both inter-swath and absolute) of lidar data are independent of the data acquisition process and the sensor model of the instrument.

Among the three steps, most of the efforts of the Cal/Val Working Group have focused on defining methodologies and algorithms to measure the inter-swath goodness of fit. Existing lidar data specifications of many organizations specify requirements for inter-swath accuracy (Heidemann 2012), or ask for calibration reports or generic calibration parameters (NGS 2009; NGA 2012). However, these specifications do not detail how the testing should be done, what measurements are acceptable, etc. Therefore, there is no widely accepted standardized process of testing the inter-swath goodness of fit or accuracy of lidar data. It is expected that the ASPRS approved document will create a standard methodology of testing and quantifying the quality of lidar data, which will improve the interoperability of data from multiple sources, generating increased confidence in the data and increasing its scientific applications.

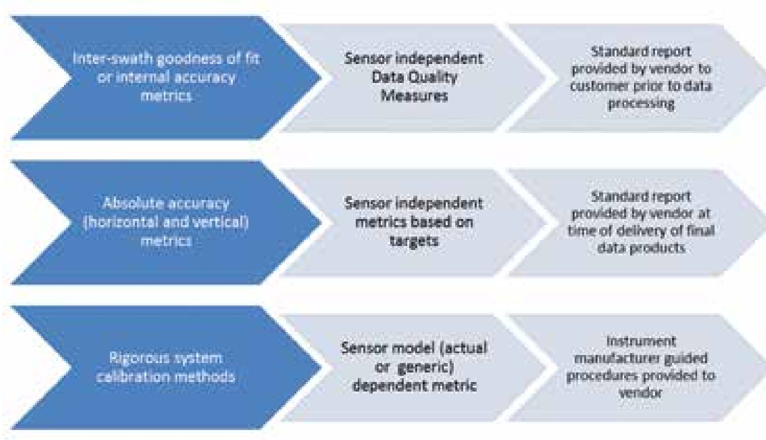

Figure 1. Framework for draft Guidelines on Geometric Accuracy and Quality of Lidar Data.

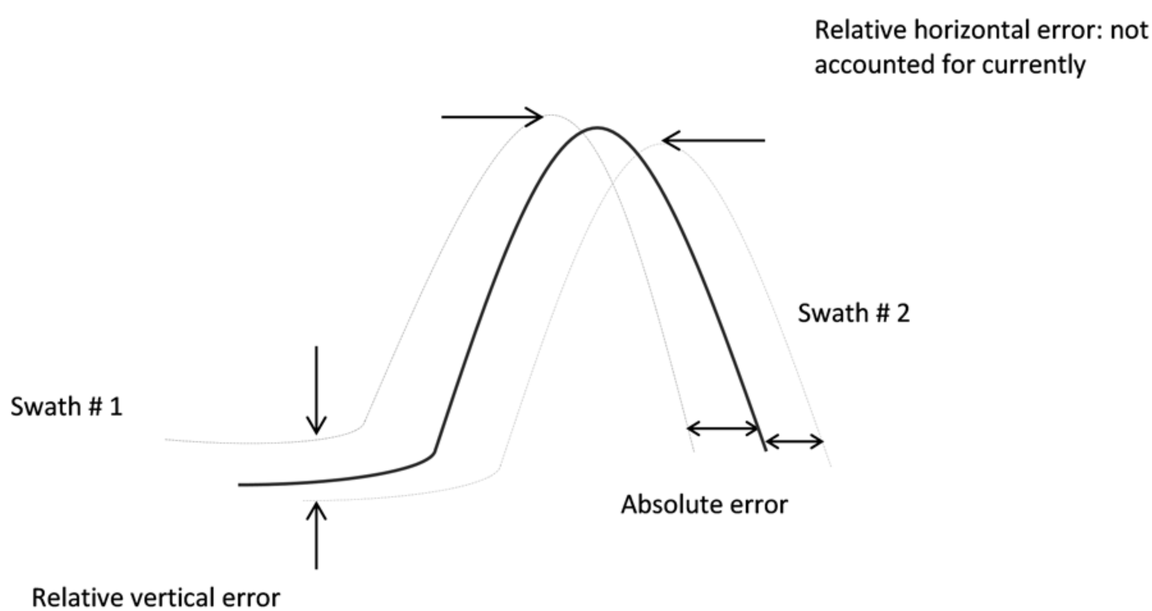

Figure 2. Surface uncertainties in hypothetical adjacent swaths. Profile of actual surface is shown as solid line while the surface defined by swath # 1 and swath # 2 are shown as dotted lines.

Internal Accuracy of Lidar Data Through DQMs

The importance of correct calibration of a lidar system to the data acquisition process and to the geometric quality of data cannot be overstated. A good calibration involves precise measurements between the various subsystems of a lidar system, including the lidar instrument, GPS receiver and IMU (Habib et. al., 2010).

Figure 2 shows a profile of a surface that falls in the overlapping region of two adjacent swaths. The surface as defined by the swaths is shown in dotted lines while the solid profile represents the actual surface. A poorly calibrated system leads to at least two kinds of errors in lidar data. The first error is that the same surface is defined in two (slightly) different ways (relative or internal error) by different swaths, and the second error is the deviation from the actual surface (absolute error). For most users of lidar data, the calibration procedures are of less concern than the data themselves. However, users would like to have a process to test the quality of calibration of the instrument, because a well-calibrated instrument is a necessary condition for high quality data. While data providers make every effort to reduce the kind of errors shown in Figure 2, there are no standard methodologies in current QC processes to measure the internal goodness of fit between adjacent swaths (i.e. internal or relative accuracy).

Current specifications documents (e.g. Heidemann 2012) do not provide guidance on measuring the inter-swath (internal accuracy) goodness of fit of lidar data. The ASPRS Cal/Val Working Group is investigating three quantities (Table 1) that measure the inter-swath goodness of fit. These measures describe the discrepancy between two overlapping point clouds and are often used to obtain optimal values of the transformation parameters.

Table 1. Data Quality Measures (DQMs) or inter-swath goodness of fit measures

Nature of surface	Examples	Data Quality Measures (DQMs)/Goodness of fit measures	Units
Natural surfaces	Ground surface, i.e. not trees, chimneys, electric lines etc.	Point to natural surface (tangential plane to surface) distance	Meters
		Point to surface vertical distance	Meters
Man-made surfaces	Roof planes	Perpendicular distance from the centroid of one plane to the conjugate plane	Meters
	Roof edges	Perpendicular distance of the centroid of one line segment to the conjugate line segment	Meters

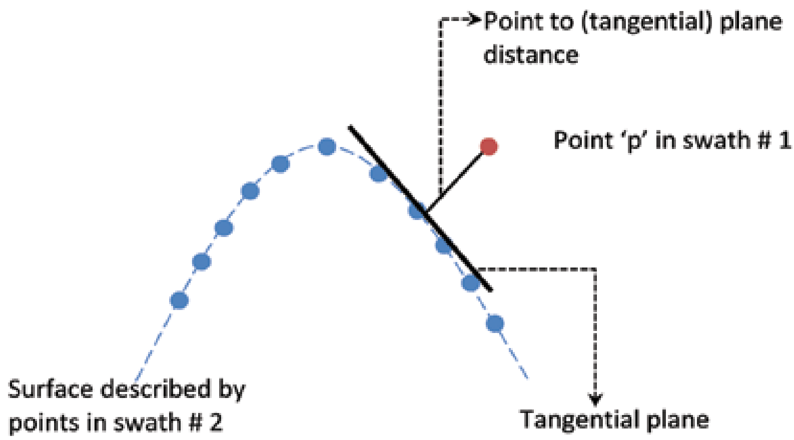

Figure 3. Representation of DQM over natural surfaces. Point 'p' (red dot) is from swath # 1 and the blue dots are from swath # 2

The DQMs are not direct point-to-point comparisons because it is nearly impossible for a lidar system to collect conjugate points in different swaths. It is easier to identify and extract conjugate surfaces and related features (e.g. roof edges) from lidar. The DQMs over natural surfaces and over roof planes assume that these conjugate surfaces are planar, and determine the measure of separation between a point and the surface (plane). The DQM over roof edges extract break lines or roof edges from two intersecting planes and measure their discrepancy.

DQM Over Natural Surfaces: Point to (Tangential) Plane Distance

This DQM is calculated by selecting a point from one swath (e.g. point 'p' in swath # 1), and determining the neighboring points (at least three) for the same coordinates in swath # 2. Ideally, the point 'p' (from swath # 1) should lie on the surface defined by the points selected from swath # 2. Therefore, any departure from this ideal situation will provide a measure of discrepancy, and hence can be used as a DQM. This departure is measured by fitting a plane to the points selected from swath # 2, and measuring the (perpendicular) distance of point 'p' to this plane.

DQM Over Roof Planes: Point to Conjugate Plane Distance

Where man-made planar features (e.g. roof planes) are present in the region of overlap, these features can be extracted and used for measuring the inter-swath goodness of fit. These planes can be extracted automatically, or with assistance from an operator. Assuming PL1 and PL2 to be conjugate roof planes in swath # 1 and swath # 2 respectively, the perpendicular distance of points used to define PL1 to the plane PL2 can be determined easily. Instead of selecting any random point, the centroid of points used to define PL1 can be determined. The centroid to plane PL2 (in swath # 2) distance can be used as a DQM to measure the inter-swath goodness of fit (Habib et. al., 2010).

DQM Over Roof Break Lines: Point to Conjugate Line Distance

If man-made linear features (e.g. roof edges) are present in the overlapping regions, these can also be used for measuring discrepancy between adjacent swaths. Roof edges can be defined as the intersection of two adjacent roof planes and accurately extracted. Conjugate roof edges (L1 and L2) in swaths #1 and # 2 should first be extracted automatically or using operator assistance. The perpendicular distance between the centroid of L1 (in swath # 1) to the roof edge L2 (in swath # 2) is a measure of discrepancy and can be used as DQM to the measure inter-swath goodness of fit (Habib et. al., 2010).

Absolute Accuracy of Lidar Data

The current practice of measuring the accuracy of lidar data is to collect GCPs in open horizontal regions and measure the discrepancy in the vertical coordinates from the lidar-derived surface. A disadvantage of using this method is that horizontal errors in the data are not accounted for. Specially designed and built targets are commonly used in photogrammetry, and can be used as a means to assess

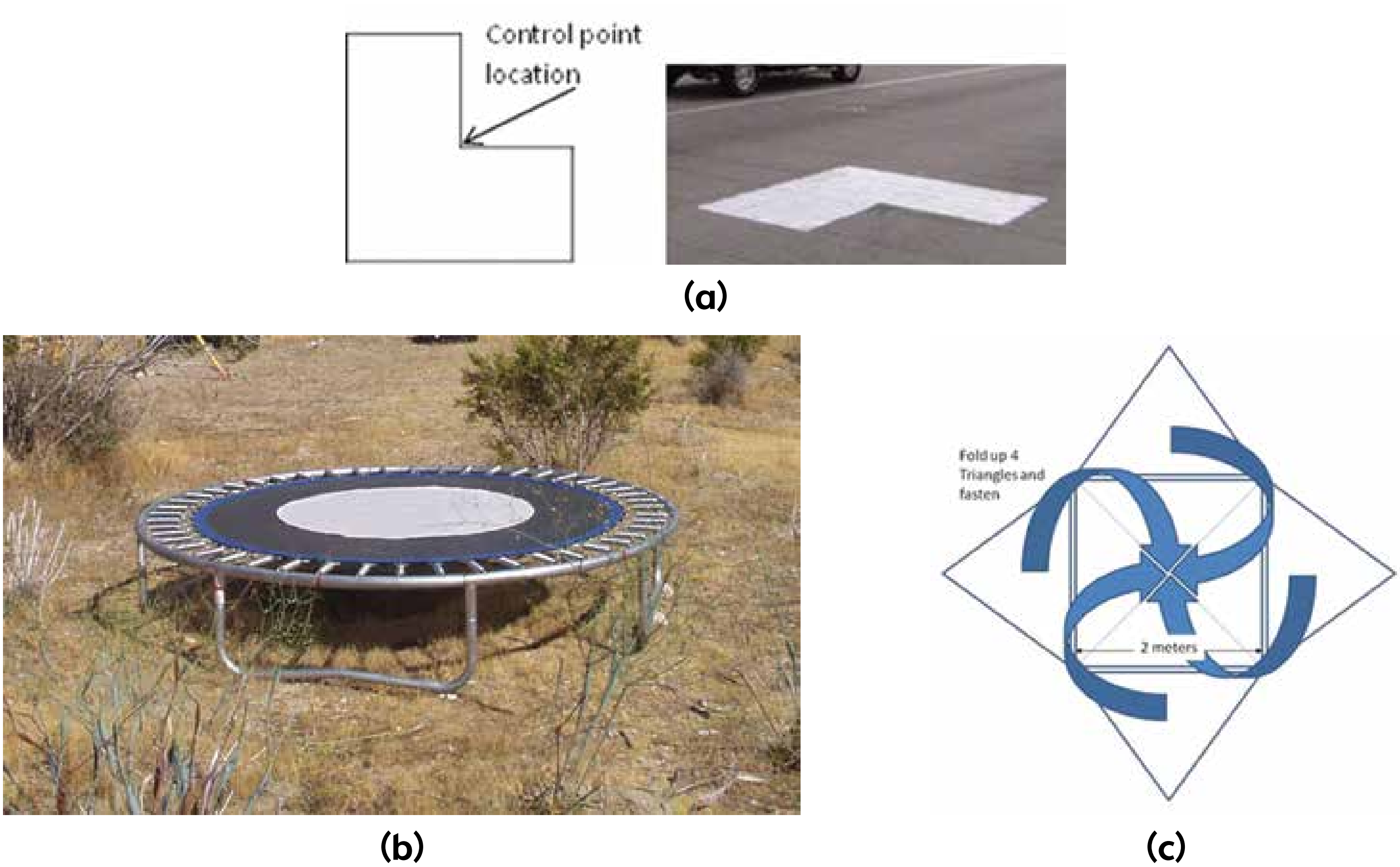

Figure 4. Design of targets (a) Painted Targets (b) Elevated Targets and (c) 3D Targets.

the horizontal and vertical accuracy of lidar data. The targets must be designed such that they can be extracted from lidar data. The targets shown in Figures 4 (a) and (b) have been used for lidar horizontal accuracy assessments (Csnayi and Toth 2007; Bethel et. al., 2006, respectively) while the target shown in Figure 4(c) (Stoker, unpublished, 2011) is in the design phase, and will be tested in 2014.

The use of targets is not new to the geospatial industry as they have been used in conventional surveying, photogrammetry and also microwave/Synthetic Aperture Radar (SAR) based mapping. Alternatively, planar features of as-built structures can be measured using a total station instrument, and the surface be used as a target for measuring absolute accuracy. Another method of using GCPs surveyed in open terrain (both horizontal and sloping terrain) is currently being investigated.

Sensor Model Based System Calibration

While the above two processes are recommended for QC of lidar data, for Quality Assurance (QA), it is recommended that a lidar system be calibrated using rigorous or semi-rigorous sensor modeling. Rigorous calibration methods are based on determining parameters describing the sensor model completely. Since many parameters associated with a complete sensor model are proprietary, software to perform rigorous calibration can only be provided by the instrument manufacturer. Rigorous methods of calibration are often a two-step process, decoupling the georeferencing portion (lever arm) from the range and boresight measurements. The rigorous calibration approach is robust, and since the process is automated the resulting swaths of data are consistent with each other and with external control.

A semi-rigorous sensor model calibration assumes a generic sensor model, and depends on the instrument manufacturer to convert parameters of their proprietary sensor model to parameters of the generic model. Examples include the Universal Lidar Error Model (ULEM) developed by NGA (NGA 2012), and Quasi Rigorous sensor model developed by Habib (Habib et. al., 2010). However, these generic models may not have the ability to completely capture all the intricacies of the original sensor model.

Current Status and Concluding Remarks

The USGS led ASPRS Cal/Val Working Group recognizes that the proposed QA/QC procedures are a departure from the currently practiced process. Before recommending these procedures to be adopted for data procurement, they have to be tested against real data sets. Hence, a prototype software tool has been developed that implements the DQMs over natural surfaces. A comprehensive test plan has been prepared and distributed to data vendors. Currently, this tool is being tested on different data sets, collected under different conditions, instruments, and by different vendors. The goal of the testing process is to test the efficiency and validity of DQMs as indicators of the goodness of fit from lidar system calibration. The lidar system calibration can have

Table 2. Error quantum to be introduced to nominal values of parameters (Note: The values are only place holders)

ΔX (m)	ΔY (m)	ΔZ (m)	Δω (seconds)	Δϕ (seconds)	Δκ (seconds)	Mirror angle scale (unit less)	Range errors (meters)
–0.13	0.7	.17	17″	–18″	72″	0.13	0.7
–0.15	–0.14	0.05	11″	106″	5″	0.15	–0.14
–0.04	0.07	0.08	71″	129″	66″	0.04	0.07

errors from many sources, including boresigh parameters. The test plan involves selecting different sets of values for the boresight parameters and generating a test dataset. Volunteers (data providers) distributed a table (similar to Table 2), with three sets of errors to be introduced to the nominal parameter values, generating three data sets per volunteer. The amount of errors introduced to the boresight parameters will vary depending on discussions with data vendors.

The volunteer will store the data sets in separate folders, while maintaining a record of errors, and process the data sets with the DQM software tool. The output generated will be analyzed to obtain summary estimates of errors in different data sets. This analysis will be followed with discussions by the ASPRS Cal/Val Working Group members on providing summary statistics of errors in the data. The publication of results of the analysis will help the customers of data to correctly specify the quality of data for procurement and scientific applications. In the next few months, processes will also be developed to determine DQMs over planar features and DQMs over linear features. Simultaneously, the USGS will also lead the Cal/Val Working Group in identifying and testing targets for absolute accuracy assessment of lidar data. The geospatial community is invited to contact Aparajithan Sampath (asampath@usgs.gov) or Greg Stensaas (stensaas@usgs.gov) if they would like to participate in the process.

The ASPRS guidelines on Geometric Accuracy and Quality of Lidar Data will incorporate the results of the analysis. The development of DQMs can have additional applications. Currently, there exists no accepted method of geometrically comparing two lidar or other 3D datasets, collected by different vendors at different times. The DQMs will allow the lidar user community to identify baseline dataset and use DQMs to directly compare any lidar data set against the baseline data and determine its relative accuracy. This test may allow scientists to perform studies such as change detection, time series analysis etc. with the confidence that they are working with geometrically consistent datasets. It is expected that this USGS- led ASPRS research will result in an across-the-board improvement in the quality of lidar data processing. The new DQMs will provide the geospatial community with the capability to procure and acquire lidar data of high and quantifiable accuracy.

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RYAN BOWE
INTERVIEW

The Young Professionals Council liason gives insight into her life as a professional GIS technician, and the benefits of being an ASPRS member.

If you had all the money and time in the world, what would you be doing right now?

Living on a ranch near Yellowstone National Park doing photography and making sure my dogs were able to go everywhere with me. I would stay active in the industry by continuing to attend conferences and mapping my photographic adventures.

What drew you to a career in the geospatial industry?

When my undergraduate advisor asked me what I wanted to do when I graduated, I said I wanted to do anthropology with a GPS unit on my back, a camera around my neck and a GIS enabled computer. I thought it would be great to photographically record cultures and to use GIS to document how the people in that culture interacted with their environment. The opportunity to work in the modern geospatial industry was a logical transition. In many ways it can be viewed as working with our current culture rather than an antiquated culture in a remote location. I thought it would be great to photographically record people and to use GIS to document how the people interact with their environment. Working at Photo Science, a Quantum Spatial Company, is my dream job on steroids. The GPS unit is on the "back" of a plane and the camera is in the belly of the aircraft. I can travel virtually to many locations by viewing the imagery and I occasionally am able to travel to the actual locations as a sensor operator.

Describe your job in five words.

Metadata, Flight Planning, Sensor Operator.

How do you describe your job to others?

I make maps at an aerial survey company. I ask them if they use Google Earth or Bing Maps and point out that the imagery base map in some locations is imagery I worked on creating and acquiring. At this point I usually start showing them camera phone photographs of the planes, mobile mapper, sensors, and some unique skylines I have seen from planes. I tell them that although I have used my personal digital camera for work photography, our cameras are much larger. I also explain that since I have the opportunity to acquire data, I have two desks -- one just happens to be in a plane -- but when I am out of the office flying, I still have to complete my in-office tasks. If we are outside, I will look up and tell them if it is or isn't a good day for remote sensing based on cloud cover.

What is your favorite ASPRS member benefit? Or what is the one thing you value most about your membership with ASPRS?

I originally joined for access to *PE&RS*. I still look forward to receiving my copy in the mail because it is my link to the profession. Although I typically am only on the acquisition side of remote sensing, *PE&RS* provides content that broadens my horizons by exposing me to more than simply acquisition. It is always exciting to see how the information created is used in a final product. And, reading *PE&RS* also allows me to consider how other individuals use the data I help to create and, based on that, how I might make it more useful to them. The news about potential or actual changes in the profession and information about evolving technology is also interesting and useful.

The workshops and webinars are a tremendous source of information. The webinar series is particularly useful to me because I do not have the budget to travel. I attended what I believe was one of the very first webinars – Preparing for ASPRS Certification – in 2009. I enjoyed it so much I attended several others.

What does your ASPRS membership mean to you? How has it impacted your work and influenced your career?

I am proud to be a member of ASPRS; they set the standards for my job. Although I was initially too intimidated to participate, I started with a book review and now I am trying to figure out on which committee I can be the most effective. No matter with which committee I choose to work, ASPRS has given me the opportunity to network with other professionals in the industry and has provided me with access to actually help write these standards.

Why did you join the ASPRS Young Professionals Council?

After becoming a URISA Vanguard Cabinet member, I heard about Young Professionals Council (YPC) and wanted to investigate. While I was talking with Ekaterina Fitos about it to take the information to my boss but she skipped a few steps and invited me to join. I was thrilled! And, being able to interact with Kim Tilley and Jim Plasker made joining YPC even better. I am really looking forward to getting to work with the new Executive Director, Michael Hauck, as he has demonstrated his support for YPC.

What would you like to see YPC accomplish?

We are off to a magnificent start; I hope we continue to carry this momentum forward. My primary focus is the mentoring program so I really want to see that develop to the point of being something that draws members to ASPRS.

What would you like to see happen in your lifetime in the geospatial industry?

I want to see the FGDC CSDGM move to ISO-1911* metadata standard. I also hope to not just see this happen but help implement the change.

If you could meet anyone, dead or alive, who would it be? What would you discuss?

I feel very fortunate to have met many of my idols. I attended North American Nature Photography Association's annual meeting as a sponsored student and met Roger Tory Peterson, Frans Lanting, Galen Rowell, Art Wolfe, Leonard Lee Rue and so many more. They all made a huge impact on my life. I have even had the opportunity to work with Lynda Wayne, my metadata heroine. But, to answer the question, I would enjoy speaking with Margaret Mead to see how she if she would implement Remote Sensing in her cultural anthropology studies.

REGION OF THE MONTH

AND THE WINNER IS...

POTOMAC REGION

The Potomac Region sponsored 13 new members during the month of January.

In recognition of their commitment to the Society, they receive the following:

- A certificate from ASPRS acknowledging their work in membership recruitment.
- ASPRS Buck$ vouchers valued at $50 to be used toward merchandise in the ASPRS Bookstore.
- This special recognition in this issue of *PE&RS* of their designation as "Region of the Month," a true display of their commitment to the Society.

This is an ongoing regional recruitment campaign. We hope other regions will be listed here in future months.

ASPRS MEMBERSHIP

ASPRS would like to welcome the following new members!

At Large
Kaleel Al-Durgham*
Zexun Geng
Debbie Mucha*
Nebiye Musaoglu
Hai-Long Pei, Ph.D.

Central NY
Bikash Basnet*
Ellen Moffat

Central US
Michael Benedettini*
Misty Carr*
Elena Galvan*
Chan-Mi Lee*

Columbia River
Ian Madin

Eastern Great Lakes
Dakotah Maguire*
Steven Ostrowski*
Changlin Xiao*

Florida
Peter Thompson*
Paul Vines*

Inter-Mountain
Lina Haggard
Rebecca Lorig*

Mid-South
Robert Feeney, II*
Michael Pate*
Caren Remillard*
Kelly Watson

North Atlantic
Shannon Saxon*
Thomas W. Tiner, CP
Catherine Yeager*

Northern California
Indumathi Jeyachandran
Ashlee Llewellyn
Paul Sutphin*
Frank Warmerdam

New England
Robert McConnell
Chris Michaud*
Barbara Shaw

Potomac
Anne Axel
Brian Cutler
Robert M. Davis*
Terrence Dolan
Joseph Governski
Jameson Harrington
Siddharth Pandey*
Amy Parsons-White*
Sean Perry*
Thomas Robillard*
Miles Saunders*
John Shaner*
Kevin Slocum

Puget Sound
Jimmy Schulz

Rocky Mountain
Dwight Chapman
Harold Cline
Curtis DeVault*
Brittaney Murphy
Linda Root

Saint Louis
Ashley Suiter*

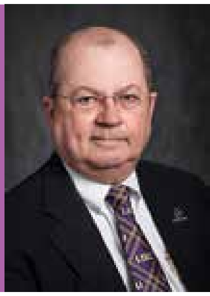
Southwest Us
Paul Ko
Sam Perez*

Western Great Lakes
Wenliang Li*
Robert S. Regis

**indicates student member*

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

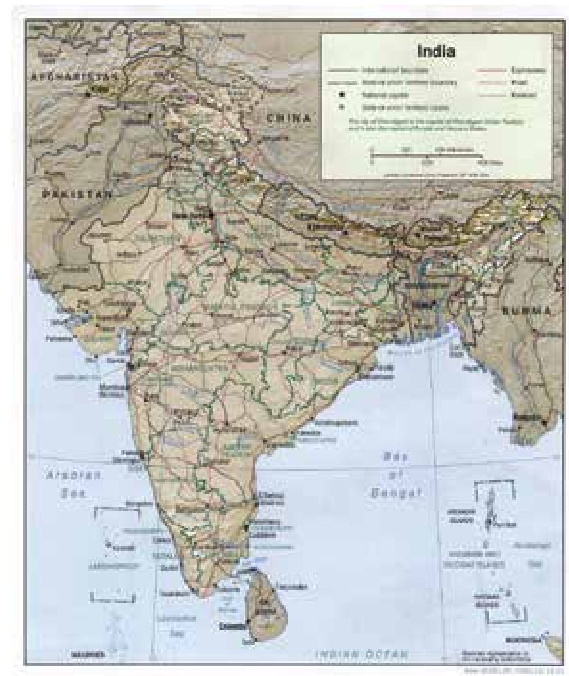
Your path to success in the geospatial community



Grids & Datums

Republic of INDIA

BY Clifford J. Mugnier, CP, CMS



The art, culture and kingdoms of India could not have spread through centuries and countries without knowledge of its geography. In the Vedic literature of over 5000 years ago, the knowledge of land was presented in a graphical form which described the extent and shape of territories. The *Brahmand Purana* of 500 *B.C.* to 700 *A.D.* gives evidence of the art of modern map-making. The art of surveying and techniques of mensuration of areas are described in *Sulva Sutra* (science of mensuration) and in the *Arth Shastra of Chanakya* written in the 3rd century *B.C.* The golden age of Indian Renaissance in the 5th century saw the towering genius Arya Bhat who wrote *Surya Siddhant* and calculated the earth's circumference to be 25,080 miles — less than 200 miles off modern measurements of the equator. Chinese and Arab travelers and many adventurers also contributed to Indian geography. Sher Shah Suri and Todar Mai's revenue maps, based on regular land survey systems, were well known in the medieval period and continued to be in practice during the mid-eighteenth century. Even today, the six huge instruments in masonry built by Raja Sawai Jai Singh in the heart of New Delhi in 1724 attract tourists from all over the world. These were designed and built by him to study the movements of the sun, moon and planets. Such instruments were also built in Jaipur to measure, among other things, time and eclipses. Another observatory was built by him in Ujjain in 1723 to forecast eclipses and movements of the sun as well as indicate the correct time. According to records, Rajaraja I of Tanjore (985–1011 *A.D.*) carried out careful surveys of the lands and cultivation. This shows that there must have been many other surveys of which no clear records have been preserved. However, information is available of the surveys instituted by Akbar during the 16th century; measurements being made by a hempen rope which was replaced by a 'jarib' of bamboos joined by iron rings. Settlement operations included the measurement and classification of lands, and fixation of rates. Systematic surveys commenced in the 18th century.

"The Survey of India traces its birth to the appointment of Major James Rennell as Surveyor General of Bengal, by Lord Robert Clive and his council, on the first of January 1767. He placed all available surveyors under Major Rennell's orders, amongst them being the Frenchman Claud Martin, who later became famous as the founder of the La Martiniere Schools. By 1773, Rennell completed surveys of the possessions before relinquishing the post of Surveyor General in 1777. Rennell surveyed Bengal and Bihar, an area of over 1500 sq. miles, producing a continuous and uniform set of maps. The surveys, however, were far from complete or accurate in detail but were sufficient to meet the needs of the time. Rennell continued his interest in England, and his first Map of Hindustan reached India in 1783. The early history of surveys in India followed the East India Company's expanding areas of influence and conquest. The next Surveyor General, Thomas Call, like many others who followed him, undertook the task of compiling an atlas embracing the whole of India. On the initiative of John Tringle, who surveyed routes with great enthusiasm, a military 'Corps of Guides' was established. This Corps also contributed largely to the surveys of the Madras Presidency for the next 30 years. It was in 1787 that Michael Topping, a marine officer, broke away from the eternal method of Perambulator Traverse and ran a 300-mile line of triangles along the coast from Madras to Palk Strait. It was he who built a permanent astronomical observatory in Madras in 1793 and founded the first surveying school in 1794. In 1796 and 1810, the Presidencies of Bombay and Madras got their own Surveyors General with the appointment of Lt Gen. Charles Reynolds and Col. Colin Mackenzie as the respective Surveyors General. It was on the first of May 1815 that the Directors, finding it wasteful to maintain three separate and independent Surveyors General, appointed Mackenzie as the Surveyor General of India. The credit of the first surveys of the Brahmaputra in Assam in 1794, and that of the Irrawady river in Burma go to Thomas Wood. The mission also collected interesting information about people, tribes and general geography of Assam and Burma, about which nothing whatever had been known before. India was one of the earliest countries to establish a regular government survey organization and to commence systematic surveys — a few years before even the Ordnance Survey of UK.

"It was very fortunate that a man of the genius and resolution of Lambton was in the subcontinent to lay the foundation of the 'Great Trignometrical Survey of India' a few years before similar projects were undertaken by France and England. In November 1799, he put forward his proposal for a Mathematical and Geographical Survey that should extend right across the Peninsula from sea to sea, controlled by astronomical observations carried out on scientific principles, capable of extension in any direction and to any distance. He started his work from Madras where, in early 1802, he measured the famous base line at Saint Thomas' Mount as a start for his triangulation, north and south through Carnatic India and across the Peninsula, with his famous 36-inch great theodolite. He completed a meridional arc from Cuddalore to Madras observing latitude at both ends and obtaining a value for the length of a degree that was essential for his scientific work. By 1815, he had nearly covered the whole Peninsula south of the river *Kistna* (Krishna) with a network of triangulations braced by main cross belts. To him goes the distinction of measuring the longest geodetic arc closest to the equator, from Cape Comorin to the 18° parallel.

THE USE OF LAPLACE STATIONS HAD NOT YET BEEN ADOPTED BY THE SURVEY OF INDIA; CONSEQUENTLY ERRORS IN AZIMUTH AND POSITION WERE INTRODUCED. THESE ERRORS ARE PARTICULARLY EVIDENT IN THE TRIANGULATION SERIES OF SOUTHERN INDIA. THE 1880 ADJUSTMENT HAS HOWEVER, REMAINED THE BASIS OF ALL INDIAN TRIANGULATION AND MAPPING. THEREFORE THERE IS NO SUCH THING AS AN "INDIAN DATUM;" IT IS ONLY AN ADJUSTMENT! (JMN, 21 JUNE 1997)

"In 1806, a subaltern came to India at the tender age of sixteen. He was none other than Lieutenant George Everest. He joined Lambton in 1818. Lambton died at work on 20 January 1823 at Hinganghat at the age of 70. General Walker recognizing his work wrote in 1870, 'of all Col. Lambton's contributions to geodesy, the most important are his measurements of meridional arcs, the results of which have been employed up to the present time in combination with those of other parts of the globe, in all investigations of the figure of the earth.' Lambton's mantle fell on the worthy shoulders of George Everest. Everest felt the need for basing the surveys on a rigid reference framework. This raised the problem of finding a suitable reference spheroid to fit the shape of the earth's gravity equi-potential surface for India and the adjacent countries. Everest realized that the Indian subcontinent was too large for basing surveys on an osculating sphere, let alone a tangent or secant plane. Everest therefore, started his control work from Kalianpur in Madhya Pradesh, more or less in the centre of India. Here he made astronomical observations and treated the astronomical latitude, longitude and the plumbline at that place as error-free. With Kalianpur as the center, he conceived covering the length and breadth of India by a gridiron of triangular chains, as opposed to the network of triangles conceived by Lambton. He brought to surveying greater accuracy and rigorous observational procedures besides devising and refining the instruments. He introduced the observation of astronomical azimuths from pairs of circumpolar stars, ray traces for long lines, *etc*. His redesigned 36-inch great theodolite is famous today. He replaced the chain with Colby's base-line apparatus and 10-foot compensation bars, with which he measured various bases. He completed the great meridional arc from Cape Comorin to Banog in the first Himalaya near Mussoorie, a length of 2400 km. Everest made the government agree to the revision of Lambton's work, based on more accurate instruments and the procedures as laid down by him. Later, in 1830, he was appointed as the Surveyor General of India but, much against the wishes of the then government, he continued to devote much time to the Great Meridional Arc. This was completed by him in 1841 and he utilized the last 2 years of his service in its computations and adjustments. The work and norms laid down by Everest have stood the test of time. The Everest spheroid, evolved by him in the year 1830, is not only still being used by India but also by Pakistan, Nepal, Burma, Sri Lanka, Bangladesh, Bhutan and other south-east Asian countries.

"We can only grasp the significance of his monumental work if we can visualize India of the early nineteenth century

— without communications and full of jungles, wild animals, robbers and disease. The average length of a side of the triangulation was about 31 miles, the maximum being about 62 miles. One cannot imagine how such long-distance observations were planned, laid down on the ground, line of sight cleared of all trees and sometimes even houses, and how big rivers and swamps were crossed. Everest, devoted to his work, did all this despite his partial paralysis and bad health. Based on his conceptualization, the gridiron network today covers the entire country and forms a solid foundation for accurate surveys and mapping for defense, development and efficient administration. It was with the help of this gridiron network that the highest peak of the world was observed and discovered in 1852 and its height declared as 29,002 ft. - *i.e.* about 8840 meters. After fresh observations and computations, the Survey of India declared its height in 1954 as 8848 meters. In 1975, the Chinese put a metallic beacon on Everest and observed it from 9 stations. They also carried out sufficient astronomical and gravimetrical measurements, the coefficient of refraction was reliably determined and the final result of the determination was declared as 8848.13 ± 0.35 meters. Sir Thomas Holdick concluded in the Standard of January 24, 1905 that 'It was officers of the Survey of India who placed his name just near the stars, than that of any other lover of eternal glory of the mountains and let it stay in witness to the faithful work not of one man but scores of men.' Everest was the first from amongst the eight Surveyors General of India to be knighted" (*Survey of India Through the Ages, by Lt. General S. M. Chadha, delivered at the Royal Geographical Society on 8 November 1990, on the eve of Sir George Everest Bicentenary celebration by the Surveyor General of India*).

Slightly more than one-third the size of the U.S., India is bordered by Bangladesh (4,053 km) (*PE&RS*, March 2008), Bhutan (605 km), Burma (1,463 km) (*PE&RS*, September 2013), China (3,380 km) (*PE&RS*, May 2000), Nepal (1,690 km) (*PE&RS*, June 20138), and Pakistan (2,912 km) (*PE&RS*, July 2009). The lowest point is the Indian Ocean (0 m), and the highest point is Kānchenjunga (8,598 m) *(World Factbook, 2014)*.

"The bulk of the geodetic triangulation in India was carried out with large theodolites between 1802 and 1882. Its simultaneous adjustment involved a decade's labor. In the 20th century, very little was done in the way of geodetic triangulation – only a few outlying series in Baluchistan and Burma having been observed. The presence of Military Survey Companies in the different theaters during WWII and in the period immediately following it enabled important gaps between the triangulation of India and its neighboring countries like Iraq, Iran, Siam and Malaya to be filled. A continuous chain of triangulation now exists from Syria to Malaya" *(Geodetic Work in India – War and Post-War, B.L.Gulatee, Empire Survey Review, No. 77, Vol. X, 1950)*.

The origin of the Indian Adjustment of 1916 is at station Kalianpur (Strong Base) where: $\Phi_o = 24° 07' 11.26''$ N, $\Lambda_o = 77° 39' 17.57''$ East of Greenwich, $\alpha_o = 190° 27' 05.10''$ from Kalianpur to Surantal, and the ellipsoid of reference is the Everest 1830 *(India)* where: $a = 6{,}377{,}301.243$ m, $1/f = 300.8017$ *(UK Military Survey, 1982)*. The adjustment depended on baselines evenly distributed throughout India. The use of LaPlace stations had not yet been adopted by the Survey of India; consequently errors in azimuth and position were introduced. These errors are particularly evident in the triangulation series of southern India. The 1880 adjustment has however, remained the basis of all Indian triangulation and mapping. Therefore there is no such thing as an "Indian Datum;" it is only an adjustment! *(JMN, 21 June 1997)*

In 1924 the "Minute Mesh" was introduced. This is a reference system consisting of meridians and parallels at one minute intervals: descriptive references are given by a convenient system of lettering, and all survey computations are done in spherical terms in the usual way" *(Geodetic Report, Survey of India, CPT. G. Bomford, R.E., 1930)*. "As the result of a decision arrived at the artillery survey conference held at Akora on 12th January 1926, two forms and a set of tables were prepared for the conversion of the spherical co-ordinates to rectangular, and *vice versa*, on Lambert's conical orthomorphic projection. This projection is also known as Lambert's second projection with two standard parallels" *(Geodetic Report, Survey of India, CPT. G. Bomford, R.E., 1928)*.

Seven separate India Zones were created in 1926 by the Survey of India, all seven having the same scale factor at origin (m_o) = 823/824 = 0.998786408, the same False Easting = 3,000,000 Indian Yards, and the same False Northing = 1,000,000 Indian Yards. The following parameters differ: Zone I has $\varphi_o = 32° 30'$ N & $\lambda_o = 68°$ E; Zone IIA has $\varphi_o = 26°$ N & $\lambda_o = 74°$ E; Zone IIB has $\varphi_o = 26°$ N & $\lambda_o = 90°$ E; Zone IIIA has $\varphi_o = 19°$ N & $\lambda_o = 80°$ E, Zone IIIB has $\varphi_o = 19°$ N & $\lambda_o = 100°$ E, Zone IVA has $\varphi_o = 12°$ N & $\lambda_o = 80°$ E, and Zone IVB has $\varphi_o = 12$ N & $\lambda_o = 104°$ E. As a hint for the readers that need the actual two standard parallels for each of the above India Zones expressed with the British Method of defining Lambert parameters; for India Zone I, the equivalent standard parallels are 35° 18' 50.3486" N and 29° 39' 18.7703" N. The requisite equations to solve for the other India Zones are in Chapter 3 of the Manual of Photogrammetry, editions 5 and 6.

Because there is no unified datum in existence for the sub-continent of India, there is a significant difference in transformation parameters from Indian 1916 to WGS84 from region to region. The Survey of India is slowly releasing geodetic and cartographic data to the general public after maintaining a significant degree of secrecy for centuries. Curiously, the India Lambert Zones are for restricted military use, and civilian applications in GIS for India seem to prefer the U.S. military's Universal Transverse Mercator Grid System.

PEOPLE

Optech announces the retirement of Dr. J. Douglas Houston, Vice President Corporate Services. As one of the first employees of the company, Dr. Houston had a personal hand in many of Optech's early advances in lidar technology, laying the groundwork for the advanced systems Optech delivers today.

While a graduate student at the University of Western Ontario and then at York University under Optech founder and Chairman Dr. Allan Carswell, Doug Houston performed the first lidar measurements ever made in Canada. Doug joined Optech soon after its founding in 1974, and was responsible for many of Optech's advances and 'firsts' in the lidar industry. His work on airborne profilometers eventually led to Optech's ALTM airborne laser terrain mappers, and he helped design and build the LARSEN 500 lidar bathymeter, a predecessor to SHOALS and Optech's CZMIL Coastal Zone Mapping and Imaging Lidar.

Doug will continue in a part-time consulting role as Glenn Farrington, VP of Operations assumes his responsibilities. Glenn has 16 years of experience with Optech, including seven years as Deputy Director and then General Manager of the Airborne Business Unit. Glenn was promoted to his VP role three years ago. With the solid scientific and engineering foundation established by pioneers like Dr. Houston, and the management expertise brought by the new Teledyne synergies, Optech is remaining true to the legacy of innovation and is poised to transform the industry once again.

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

Hello!

Let me first wish you a Happy New Year!

I am inviting you to contribute chapters: To the "Handbook of Research on Geospatial Science and Technologies" scheduled to be published by IGI Global (formerly Idea Group Inc.), please see the attachment and please visit www.igi-global.com for more information. This publication is anticipated to be released in 2015.

For more information about this book, please visit: http://www.igi-global.com/publish/call-for-papers/call-details/1165.

To submit a Chapter, please visit the following LINK: http://www.igi-global.com/ChapterSubmission.aspx?ProjectId=a5f92966-cbf1-43e5-a966-95ea2c4de4dd.

Please distribute as much as possible so that this call for chapters could reach the types of professionals for this publication.

Kind Regards,

Joyce Maphanyane

Inquiries

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Advertiser Index

High Resolution Satellite Imagery

Ian Dowman, Karsten Jacobsen,
Gottfried Konecny, and Rainer Sandau

Whittles Publishing: Dunbeath, Scotland, UK. 2012. 248 pp., diagrams, maps, images, color plates, index.
ISBN 978-184995-046-6 (Hardcover)
$122.20

Reviewed by: Tuna Kalayci, FORTH, Institute for Mediterranean Studies. Laboratory of Geophysical – Satellite Remote Sensing and Archaeo-environment. Rethymno 74100, Crete, Greece

***High Resolution Optical Satellite Imagery*, written by** Ian Dowman, Karsten Jacobsen, Gottfried Konecny, and Rainer Sandau, explores the characteristics of high resolution optical sensors and the ways in which optical imagery are acquired and processed. By itself, the term, "high resolution", is problematic since there is little consensus on what is considered "high resolution". In other words, where does the separation between high resolution and low resolution sensors begin? The book, however, sufficiently overcomes this problem by discussing systems, such as ASTER and SPOT alongside sensors with a ground sample distances (GSD) one meters or less. The book stands as a good reference for students and professionals.

The book can be divided into three parts. Part One (Chapter 1: Satellite Imaging Technology; Chapter 2: History of Optical Sensors in Space) is an introduction to satellite systems, concepts and terminologies as well as the history of space flight. This step-by-step introduction is helpful for readers with limited remote sensing expertise. However, more advanced readers will still enjoy reading these introductory chapters.

Part Two (Chapter 3: Principles of High Resolution Optical Sensors; Chapter 4: Sensors with a GSD of greater than 1m up to 16m; Chapter 5: Sensors with a GSD of 1 m or less) provide extensive theoretical and practical knowledge on "high resolution optical satellite imagery". In Chapter 3, Rainer Sandau proficiently summarizes the engineering and mathematics behind a generic optical sensor. The proceeding chapters investigate specific high resolution sensors in detail and provide informative tables and charts for an easier read. These chapters succinctly compile information ranging from camera characteristics to company profiles in charge of building these sensors.

Part Three (Chapter 6: Calibration, Sensor Models and Orientation and Chapter 7: Processing and Products) focuses on photogrammetric processing and remote sensing products. Topics discussed include rigorous models Rational Polynomial Coefficients (RPC) as well as Image Matching for Digital Elevation Model (DEM) generation, orthorectification, and data fusion. "Discussions on modeling, orientation and imagery products may seem limited to advanced readers, but these chapters still remain comprehensive so that they remain satisfactory to many. Finally, the book is closed by Chapter 7: Conclusions and Future Developments, where planned and potential missions are discussed.

Overall, the book fills an important gap in studies on high spatial resolution satellite data. Discussing specific sensor technologies and exploring their developmental trajectories offer a great opportunity not only for remote sensing specialists, but also for other scholars who are dealing with spatial data. The authors explain introductory topics in sufficient detail and open discussions for more advanced subjects. While doing so, the authors successfully cover "high resolution optical satellite imagery" in this relatively short book.

Due to the ways in which the book is organized some discussions overlap (e.g. CORONA camera system). This doesn't affect the flow, yet the number of such instances is large enough to be noticed by the reader. In various cases, the authors guide the reader to other chapters, sections and sub-sections for further explanation and references.

"High Resolution Optical Satellite Imagery" would have been more complete with an additional chapter on case studies using high resolution imagery. Spatial disciplines increasingly enjoy high resolution imagery due to wider availability and decreasing costs. There are exemplary studies throughout the book, but, these studies focus on sensor performances rather than how high-resolution imagery is exploited.

In summary, the author's provide an easy-to-read and high-quality book with sufficient number of color plates and graphs. The authors of the book were able to create a useful reference on the subject for a wide audience, including scientists and engineers. Scholars working with spatial data will also find this reference extremely valuable in their studies.

BE AN ASPRS MEMBER CHAMPION

ASPRS is recruiting new members and YOU benefit from each new member YOU champion. Not only can you contribute to the growth of ASPRS, but you can earn discounts on dues and merchandise in the ASPRS Store.

Member Champions by Region from January 1, 2013 – January 31, 2014

Alaska
Sharon W. George
Josef Jansa

Central New York
William M. Stiteler, CMS
Jane M. Read

Central US
Kevin P. Price

Columbia River
Steven P. Lennartz, CMS
Sarah Praskievicz
Michael S. Renslow, CP

Eastern Great Lakes
Charles W. Emerson
Kin M. Ma
William F. Welsh

Florida
Bon A. Dewitt
Brian E. Murphy, CP
Xiaojun Yang

Mid-South
Eugenio Arima
Haluk Cetin

New England
Russell G. Congalton

North Atlantic
Bradley Foltz, CP

Potomac
Allan Falconer
Barry N. Haack
Ashley Christine Holt
Michael Krimmer
John F. Manzer
Susan D. Oakley
Janice Ouellette
Joshua Sisskind

Puget Sound
L. Monika Moskal

Rocky Mountain
Michaela Buenemann

Saint Louis
Ming-Chih Hung
Bingqing Liang
Todd Wever
Bradley C. Rundquist

Western Great Lakes
Qihao Weng, Ph.D.
Andrew James Williams

Member Champions by number of new members recruited

Recruited from 1 to 4 new members
Eugenio Arima
Michaela Buenemann
Russell G. Congalton
Bon W. Dewitt
Charles W. Emerson
Allan Falconer
Bradley Foltz, CP
Sharon W. George
Ashley Christine Holt
Ming-Chih Hung
Josef Jansa
Michael Krimmer
Kin M. Ma
John F. Manzer
L. Monika Moskal
Brian E. Murphy, CP
Susan D. Oakley
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Sarah Praskievicz
Jane M. Read
Michael S. Renslow, CP
Bradley C. Rundquist
Joshua Sisskind
William M. Stiteler, CMS
William F. Welsh
Qihao Weng, Ph.D.
Todd Wever
Andrew James Williams

Recruited 5 and more new members
Haluk Cetin (7)
Barry N. Haack (8)
Steven P. Lennartz, CMS (15)
Xiaojun Yang (11)
Bingqing Liang (6)
Kevin P. Price (5)
Karen L. Schuckman, CP (14)

ASPR Member Champions is our yearly recruitment drive; by including their membership number on their recruit's membership application, ASPRS members can receive discounts on dues and books as a thank you for helping increase membership. For membership materials, contact ASPRS at 301-493-0290, ext. 109/104 or email: members@asprs.org.

The perks of being an ASPRS Member Champion include discounts on ASPRS dues and books, gift certificates to the ASPRS Bookstore, and free membership. For a full listing of ASPRS Member Benefits, visit: http://www.asprs.org

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www.applanix.com
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Easton, Maryland
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BNP Media, Point of Beginning Magazine
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www.e-geos.it
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KLT Associates, Inc.
Peabody, Massachusetts
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Member since: 2/2006

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Microsoft UltraCam Team (Vexcel Imaging, GmbH)
Graz, Austria
www.microsoft.com/ultracam
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NASA Earth Science Division
Washington, DC
www.appliedsciences.nasa.gov
Member Since: 1/2001

NOAA National Geodetc Survey
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www.ngs.noaa.gov
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North West Group
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www.nwgeo.com
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NovAtel, Inc.
Calgary, Alberta, Canada
www.novatel.com
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www.usgs.gov
Member Since: 4/2002

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[formerly International Institute for Geo-Information Science and Earth Observation (ITC)]
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www.itc.nl
Member Since: 1/1992

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www.urbanrobotics.net
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USDA/National Agricultural Statistics Service
Fairfax, Virginia
www.nass.usda.gov
Member Since: 6/2004

Watershed Sciences, Inc.
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www.watershedsciences.com
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www.wilsonco.com
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Comparison of Simulated HyspIRI with Two Multispectral Sensors for Invasive Species Mapping

Aaryn D. Olsson and Jeffrey T. Morisette

Abstract

This paper assesses the potential of a single HyspIRI scene to estimate cover of the non-native invasive buffelgrass (Pennisetum ciliare) in a heterogeneous Sonoran Desert scrub ecosystem. We simulated HyspIRI (60 m) along with two multispectral sensors, Thematic Mapper (TM; 30 m) and Advanced Spaceborne Thermal Emission and Reflection Spectrometer (ASTER; 15 m), from high-resolution Airborne Visible/Infrared Imaging Spectrometer (AVIRIS; 3.2 m) imagery in an area infested by buffelgrass near Tucson, Arizona. We compared classification accuracies of all simulated sensors at spatial resolutions of 15 m, 30 m, and 60 m to evaluate tradeoffs of spectral and spatial resolution across the sensors. Although spectroscopically superior to Landsat TM and ASTER, ASTER easily outperformed HyspIRI for small infestations (225 m^2) on account of its spatial resolution. Shortwave-infrared bands near 2.2 µm were key indicators for both HyspIRI and ASTER, highlighting the benefit of narrow-wave SWIR for mapping invasive species in arid ecosystems.

Introduction

Invasive species pose a rising global ecosystem challenge due to impacts to ecosystem structure, function, diversity, nutrient cycling, and disturbance regimes (Mooney and Hobbs, 2000). Managers and researchers require readily available data and tools for mapping and monitoring invasive species, yet the readily available satellite data are often too coarse spatially, spectrally, temporally, or a combination thereof to effectively and consistently map invasive species (Turner *et al.,* 2003). While deca-resolution (Morisette, 2010) broadband multispectral satellite imagery with regular return intervals such as the Landsat and Satellite Pour l'Observation de la Terre (SPOT) families of sensors have been widely successful at mapping vegetation communities and land-cover change, mapping individual plant species has been limited to cases in which large continuous areas have become invaded (e.g., Peterson, 2005; Bradley and Mustard, 2006) and typically requires distinct phenological differences between natives and invaders (Huang and Asner, 2009). Many would argue that invasions that reach this scale are either already unmanageable, or their presence is already well known. Regardless, small populations can play a disproportionate role in the rate of spread and treatment efficacy of invasions (Moody and Mack, 1988; Frid and Wilmshurst, 2009). Thus, mapping small populations remains a critical need for resource managers facing plant invasions.

A key limitation of multispectral imaging in dryland ecosystems has been an inability to consistently discriminate between mineral soil and non-photosynthetic vegetation (NPV) (Olsson *et al.*, 2011). Mineral soil and NPV have distinct wavelength features in the SWIR, particularly in the 2.0 to 2.4 µm region (Asner and Lobell, 2000; Nagler *et al.*, 2003). The multispectral SWIR instrument on ASTER promised to provide this capacity, but unfortunately, it suffered a series of failures that first limited its utility (Iwasaki and Tonooka, 2005) and ultimately rendered the SWIR instrument completely inoperable (ASTER Science Office, 2009).

Invasive species mapping has been more successful when hyperspectral imagery has been used in classification or target detection. AVIRIS and Hyperion have been used to map invasions (Ustin *et al.*, 2001; Underwood *et al.*, 2003; Lass *et al.*, 2005; Pengra *et al.*, 2007; Asner *et al.*, 2008), yet both have their drawbacks. AVIRIS is an airborne sensor with 224 contiguous band channels measuring upwelling radiance at 0.01 µm intervals between 0.40 and 2.50 µm. As an airborne sensor it can be flown at varying altitudes, resulting in spatial resolutions between 2 and 20 meters. Commissioning AVIRIS requires a research experiment proposal and is effectively limited to a small number of projects and locations. Hyperion is an experimental sensor mounted on the NASA EO-1 satellite and has 220 bands measuring radiance at 0.01 µm intervals between 0.40 and 2.50 µm at a 30 m spatial resolution. While Hyperion can visit the same location on a regular basis (every five to ten days with off-nadir pointing), there is a very limited collection cycle due to its narrow swath and its limited lifetime. As such, spatial coverage and temporal resolution from either of these two sensors are limited. Also, as an experimental instrument, Hyperion has issues with cross-track calibration and low signal-to-noise ratio (SNR), particularly in the shortwave-infrared (Datt *et al.*, 2003; Kruse *et al.*, 2003). All of these issues limit the usefulness of these two national assets to contribute to any operational invasive species detection program.

HyspIRI (Hyperspectral InfraRed Imager) is one of NASA's "decadal survey" missions that aims to address these and other monitoring concerns (NAS, 2007). HyspIRI is planned to have an imaging spectrometer that measures upwelling radiance from the visible to short wave infrared (VSWIR: 0.38 µm

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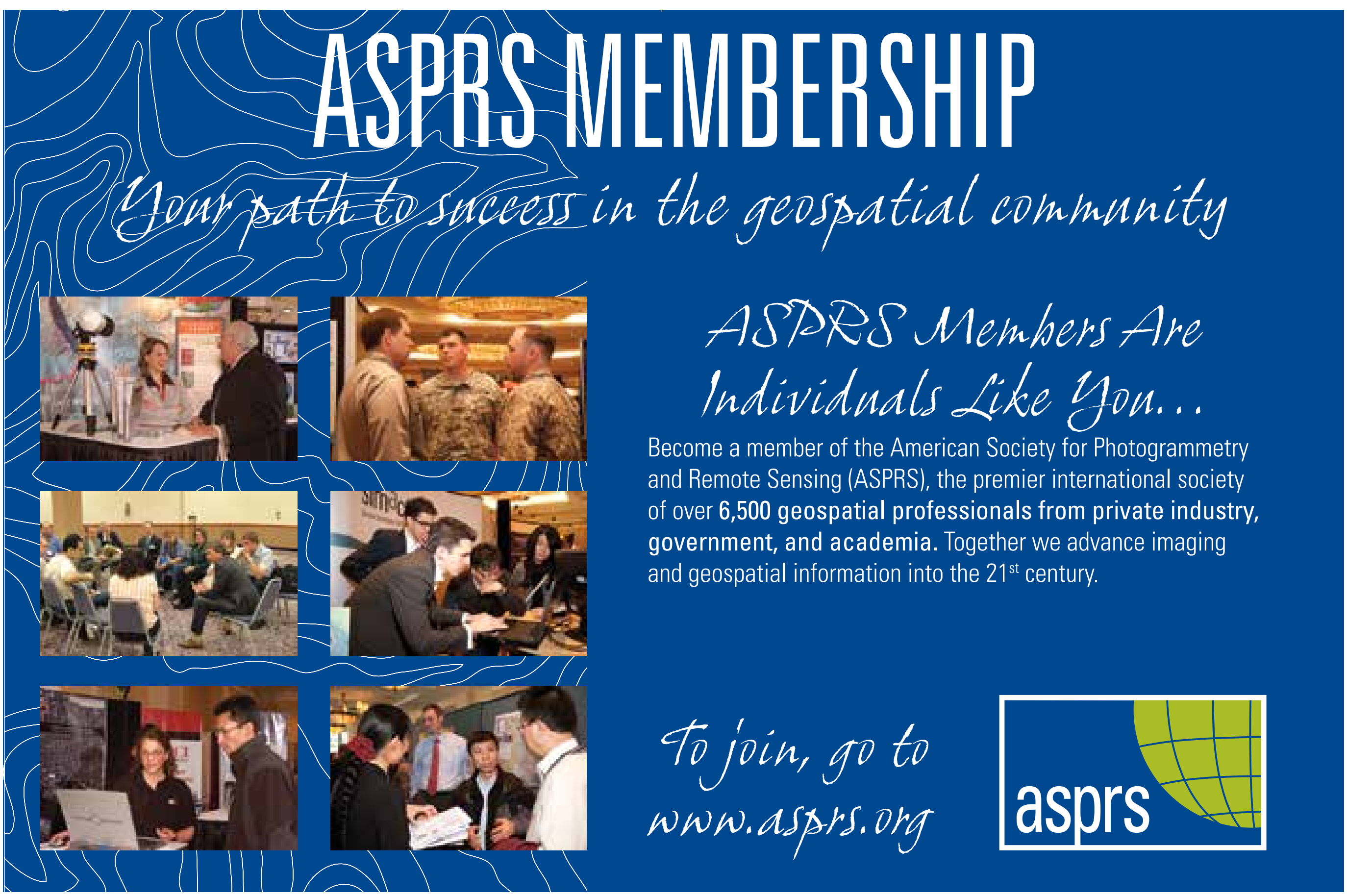

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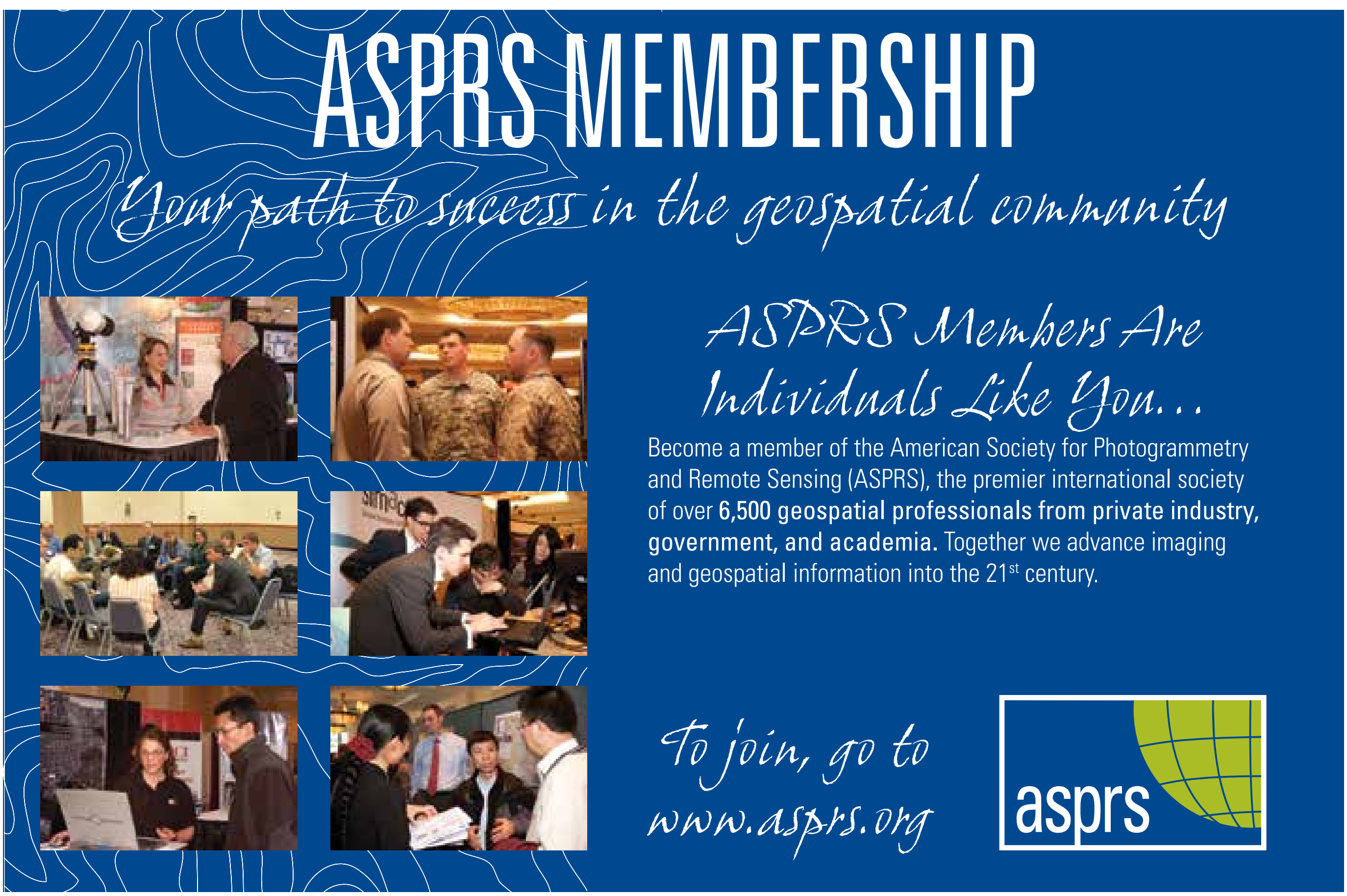

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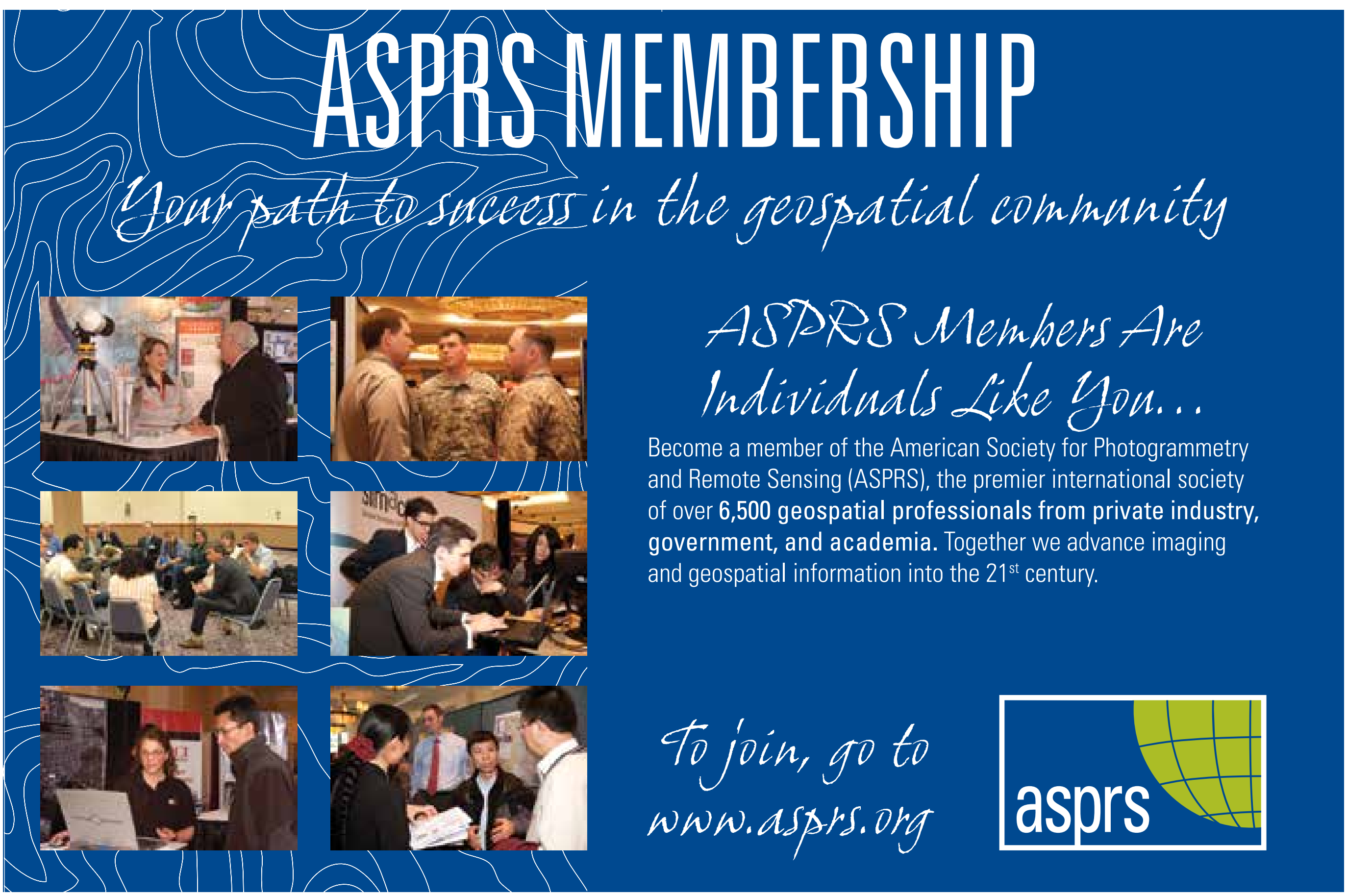

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Forthcoming Articles

Mostafa Kabolizade, Hamid Ebadi, and *Mehdi Mokhtarzade*, Automatic Building Extraction Using a Fuzzy Active Contour Model.

Ali Akbar Matkan, Mohammad Hajeb, and *Saeed Sadeghian*, Road Extraction from Lidar Data Using Support Vector Machine Classification.

George Ch. Miliaresis, Daily Temperature Oscillation Enhancement of Multitemporal LST Imagery.

Minfeng Xing, Binbin He, Xingwen Quan, and *Xiaowen Li*, An Extended Approach for Biomass Estimation in a Mixed Vegetation Area Using ASAR and TM Data.

Lian P. Rampi, Joseph F. Knight, and *Keith C. Pelletier*, Wetland Mapping in the Upper Midwest United States: An Object-Based Approach Integrating Lidar and Imagery Data.

Sara Jurado, Marta Yebra, Patricia Oliva, and *Emilio Chuvieco*, Laboratory Measurements of Plant Drying: Implications to Estimate Moisture Content from Radiative Transfer Models in Two Temperate Species.

Niva Kiran Verma, David W. Lamb, Nick Reid, and *Brian Wilson*, A Comparative Study of Land Cover Classification Techniques for "Farmscapes" Using Very High Resolution Remotely Sensed Data.

Taoyang Wang, Guo Zhang, Deren Li, Xinming Tang, Yonghua Jiang, Hongbo Pan, and *Xiaoyang Zhu*, Planar Block Adjustment and Orthorectification of ZY-3 Satellite Images.

Pengjie Tao, Luping Lu, Yong Zhang, Biao Xu, and *Songbai Zou*, On-Orbit Geometric Calibration of the Panchromatic/Multispectral Camera of the ZY-1 02C Satellite based on Public Geographic Data.

I*man Khosravi, Mehdi Momeni*, and *Maryam Rahnemoonfar*, Performance Evaluation of Object-Based and Pixel-Based Building Detection Algorithms from Very High Spatial Resolution Imagery.

So-Ra Kim, Anup K. Prasad, Hesham El-Askary, Woo-Kyun Lee, Doo-Ahn Kwak, Seung-Ho Lee, and *Menas Kafatos,* Application of the Savitzky–Golay Filter to Land Cover Classification Using Temporal MODIS Vegetation Indices.

Bo Yu, Li Wang, Zheng Niu, and *Muhammad Shakir*, An Effective Morphological Index in Automatic Recognition of Built-Up Area Suitable for High Spatial Resolution Images as ALSO and SPOT Data.

Daniel M. Howard and *Bruce K. Wylie*, Annual Crop Type Classification if the U.S. Great Plains for 2000 to 2011.

Dora Roque, Nuno Afonso, Ana M. Fonseca, and *Sandra Heleno*, OBIA Flood Delimitation Assisted by Threshold Determination with PCA.

Amin Alizadeh Naeini, Mohammad Saadatseresht, and *Saeid Homayuni*, Automatic Estimation of Number of Clusters in Hyperspectral Imagery.

Special Issue "Remote Sensing of Soils for Environmental Assessment and Management" (Guest Editor: Steve DeGloria)

Yuki Hamada, *Jack A. Gilbert*, *Peter E. Larsen*, and *Madeline J. Norgaard*, Toward Linking Aboveground Properties and Soil Microbial Communities Using Remote Sensing.

Zamir Libohova, *James Doolittle*, *Reed Sims*, *Thomas Villars*, and *Larry T. West*, Mapping the Subaqueous Soils of Lake Champlain's Missisquoi Bay Using Ground-Penetrating Radar, Digital Soil Mapping , and Field Measurements.

Katherine E. Williams and *Sharolyn J. Anderson*, Geostatistical Methods for Predicting Soil Moisture Continuously in a Subalpine Basin.

Zachary P. Sugg, *Tobias Finke*, *David C. Goodrich*, *M. Susan Moran*, and *Stephen R. Yool*, Mapping Impervious Surfaces Using Object-oriented Classification in a Semiarid Urban Region.

Travis W. Nauman, *James A. Thompson*, and *Craig Rasmussen*, Semi-Automated Disaggregation of a Conventional Soil Map Using Knowledge Driven Data Mining and Random Forests in the Sonoran Desert, USA. Shiliang Su, Rui Xiao, and Yuan Zhang, Monitoring Agricultural Soil Sealing in Peri-Urban Areas Using Remote Sensing.

CALENDAR

APRIL 2014

7–10, RSCy2014, Paphos, Cyprus. For more information, visit http://www.cyprusremotesensing.com/rscy2014/

9–11, Association of American Geographers Annual Meeting, Tampa Convention Center, Tampa, Florida, USA. For more information, visit: http://www.aag.org/cs/annualmeeting

MAY 2014

5–9, SPIE DSS 2014, Baltimore, Maryland. For more information, visit http://spie.org/defense-security.xml?WT.mc_id=RCal-DEFW

7–8, 2014 Indiana GIS Conference – "Mapping a Difference". Indianapolis, Indiana. For more information visit www.igic.org/conference

7–9, ICAO 2nd Air Transport Symposium. Montréal, Canada. For more information visit www.icao.int/Meetings/iats2014/

19–21, PAS Technology Conference, Houston, Texas. For more information, visit http://www.pas.com/ptc

28–29, GEO Business 2014, Business Design Centre, London, UK. For further information visit www.geobusinessshow.com.

JULY 2014

15–18, Cybernetics and Information Technologies, Systems and Applications: CITSA 2014 & Engineering and Technological Innovation: IMETI 2014, Orlando, Florida. For more information, visit http://www.iiisconferences2014.org/citsa or http://www.iiisconferences2014.org/imeti.

AUGUST 2014

2–10, 40th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events — "COSPAR 2014", Moscow, Russia. For more information, visit http://www.cospar-assembly.org or http://cospar2014moscow.com/.

17–21, Optical Engineering + Applications 2014 - Part of SPIE Optics + Photonics, San Diego Convention Center, San Diego, California, USA.

SEPTEMBER 2014

8–11, GIS-Pro 2014: URISA's 52nd Annual Conference, New Orleans, Louisiana. For more information, visit www.gis-pro.org or www.urisa.org.

OCTOBER 2014

7–9, INTERGEO and imaGIne-2 Congress, Berlin, Germany.

NOVEMBER 2014

17-20, ASPRS 2014 Pecora 19 Symposium, Denver, Colorado. Web site launch expected for February 2014.

MAY 2015

4–8, ASPRS 2015 Annual Conference, Tampa, Florida. For more information, visit www.asprs.org.

Comparison of Two Panoramic Sensor Models for Precise 3D Measurements

Shunping Ji, Yun Shi, Zhongchao Shi, Anmin Bao, Junli Li, Xiuxiao Yuan, Yulin Duan, and Ryosuke Shibasaki

Abstract

In this paper, the system errors produced by the most widely used ideal panoramic camera model for a close-range multi-camera rig are indicated and analytically modeled according to a rigorous panoramic camera model, and a comprehensive comparison between the two models is given. First, the 3D localization errors of the ideal model are analyzed that shows the correlations with the object-image distance and the viewing angles. Second, the epipolar errors are analyzed and are observed to exhibit changes with the rotation angles and z-coordinates of the image points. Finally, tests are carried out in space resection, epipolar constraints, and bundle adjustment with different sensor models. The outdoor tests with small object-image distance (several meters) show the difference between the two models is notably slight. In contrast, the indoor tests with larger object-image distance (more than 15 m) show the rigorous model produces 2 cm better measurement accuracy than the ideal.

Introduction

In many research studies and applications in recent years (Li *et al*., 2004; Anguelov *et al*., 2010), the close-range panoramic camera has been employed in place of a traditional plane camera because it features full panoramic information in a single image and a simple structure: one projection center and one projection sphere or cylinder. However, compared with a plane camera, larger geometric distortions exist in a panoramic camera or in a fish-eye camera even with a much smaller field of view, which may result in poor imaging quality. From a manufacturing perspective, there are three main methods used to overcome the large distortions. One method employs a dioptric multi-camera rig system, which reduces and shares the deformation equally over several separate and fixed fish-eye lenses. Further image stitching is required to form an entire panoramic image, which causes the main drawback of this structure that the projection radius should be fixed for a best stitching effect. The Ladybug® system is an example of this case (Sato *et al*., 2004; Sato and Yokoya, 2010; Ladybug, 2013). The other method uses a linear-array-based camera, which can obtain seamless panoramic images with a vertical and turntable axis, such as the EYESCAN camera system (Schneider and Maas, 2006; Amiri and Gruen, 2010). This structure is not suitable for high-speed platforms, and static or low-speed platforms are preferred (Geyer and Kostas, 2001). A catadioptric system is the third type of panoramic camera composed of several lenses and parabolic mirrors (Geyer and Kostas, 2001; Barreto and Araujo, 2005). This paper concentrates on the multi-camera rig system with spherical projection.

The basic projective geometry of a panoramic camera is still represented by the ideal pinhole model, which describes the co-linearity that 3D object points, corresponding image points in the sphere, and the panoramic center are in a line (see Figure 1a). Kaess and Dellaert used a multi-camera rig for simultaneous localization and mapping (SLAM) with the pinhole spherical sensor model (Kaess and Dellaert, 2010). Paya *et al.* (2010) concentrated on the global description of each omni-directional image. Gutierrez *et al.* (2011) concentrated on the rotation and scale invariance of descriptor patches with a spherical camera model. Spherical perspective transformation functions and stereo-homographies based on the pinhole model are also covered by Mei *et al.* (2008). In Silpa-Anan and Hartley (2005) the fundamental matrix of the pinhole model is used as a geometric constraint between two views. The pinhole model for spherical imaging used in these articles (also referred to in this paper as the ideal panoramic camera model) is adopted under the assumption that the camera contains a unique spherical center as in Figure 1a. In fact, a multi-camera rig system does not contain an entire sphere but consists of several separate lenses with different projection centers and focal lengths (see Figure 1b). This internal structure may introduce additional system errors if the ideal panoramic camera model is applied.

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Ensemble Learning with Multiple Classifiers and Polarimetric Features for Polarized SAR Image Classification

Alim. Samat, Peijun Du, Muhammad Hasan Ali Baig, Sumit Chakravarty, and Liang Cheng

Abstract
Polarimetric SAR *(PolSAR) image processing has become a hot research topic in* SAR *remote sensing field in recent years. However, due to the complexity of the image and limited availability of advanced techniques, PolSAR image processing is still a challenging issue. In this paper the suggestion of ensemble learning (EL) is introduced into PolSAR image classification by integrating various polarimetric features and multiple classifiers. The most popular ensemble learning methods, including Bagging, AdaBoost, and Rotation Forest are adopted to combine multiple classifiers and polarimetric features. The proposed classification scheme is evaluated on three real PolSAR data. Experimental results shows that the covariance and coherence features can give better performance than other polarimetric decomposition features, and complementary between different polarimetric decomposition features improving the classification performance. Although a weak classifier gives unsatisfactory classification accuracy on polarimetric decomposition features, the performance can be highly improved by using EL strategies.*

Introduction
Land cover classification is one of the primary objectives of remotely sensed image processing, analysis, and practical application. Synthetic Aperture Radar (SAR) opens new opportunities for land cover classification owing to its day and night, all-weather, and high-resolution observation capability to the Earth's surface. But due to the low information content of an individual SAR image, single-polarization or single-band SAR data cannot provide highly accurate land cover classification maps (Herold *et al.*, 2004; Lee *et al.*, 2002). On the contrary, PolSAR images contain a large amount of potential information which is directly related to physical properties of natural media and backscattering mechanism. Therefore, full polarized SAR imagery classification has become a popular and challenging problem in recent years due to its potential applicability in different fields. With the goal of achieving high classification accuracy, many supervised, unsupervised, and semi-supervised classification methods have been developed. Usually, the adopted features in classification include scattering matrix elements, covariance matrix elements and coherent matrix elements, and polarimetric decomposition features (Cloude *et al.*, 1997; Du *et al.*, 1996; Krogager, m 1994; Qi *et al.*, 2012; Song *et al.*, 2007; Wang *et al.*, 2013).

Generally, developing advanced classifiers, or optimizing the input features or adopting novel pattern recognition methods are the three common ways get better classification performance. It is worth noting that, finding the optimal features and best classifier is always hard, maybe even impossible. However, a better classification result may be achieved by combining multiple classifiers and various features by using ensemble learning (EL) strategies.

Since "strong and weak learn ability are equivalent" was proofed by Robert E. Schapire (Schapire, 1990), more options are available to get an improved classification performance through EL, which can integrate the benefits of different features, classifiers, and combination methods. As an advanced machine learning framework, EL is able to boost weak learners, working slightly or obviously better than random guessing to strong learners, thus making accurate predictions.

In spite of the considerable amount of work on the use of EL for remote sensing image classification in the past years, few applications of EL to PolSAR image classification could be found in literature (Jiong *et al.*, 2008; Loosvelt *et al.*, 2012; Min *et al.*, 2009; She *et al.*,2007). In this paper, EL techniques such as Bagging, AdaBoost, and Rotation Forest are introduced to PolSAR image classification based on different polarimetric features. To evaluate the performance of various EL methods, some benchmark classifiers such as support vector machine (SVM), logistics decision tree, simple logistic decision tree, and k-Nearest Neighbor are experimented and compared. Besides, different ensemble strategies for classifier combination such as voting, stacking generation, and multi-

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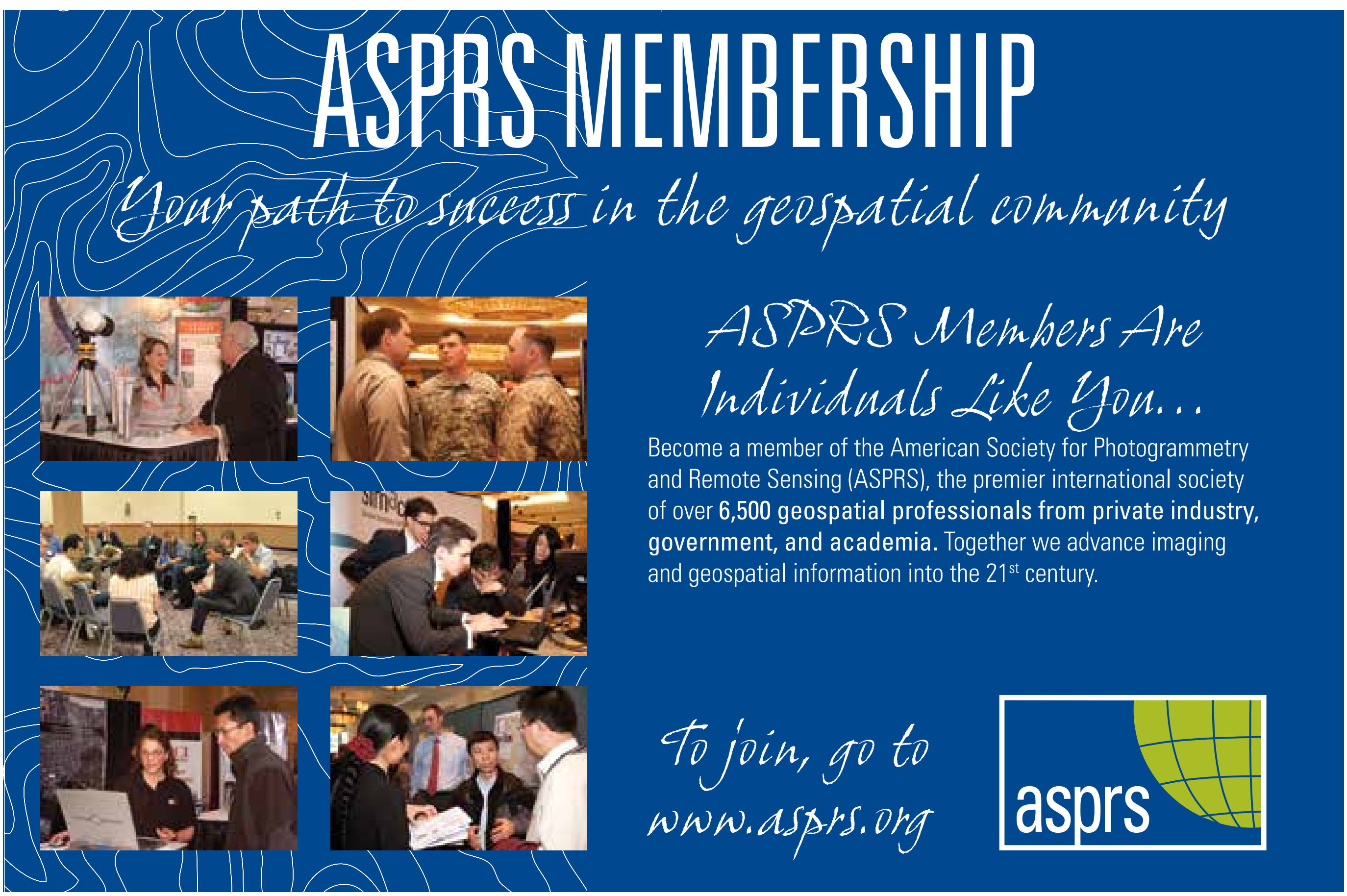

Call for Papers

Advances and New Perspectives in Geographic Object-Based Image Analysis

Guest Editors

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Deadline for submission of manuscripts: August 1, 2014

Tentative publication date: June 1, 2015

A Special Issue oin "Advances and New Perspectives in Geographic Object-Based Image Analysis" will focus on recently introduced theories and innovations as well as future research trends in Geographic Object-Based Image Analysis (GEOBIA) by remote sensing scientists and professionals.

Since emerging early in the 21st century, GEOBIA has incorporated and further upgraded established concepts in remote sensing and interrelated spatial sciences. It has gained wide popularity and attracted the interest of both the scientific and professional communities, for its efficiency to provide enhanced and reliable geospatial intelligence. The growing interest in GEOBIA is demonstrated by the increasing number of high-quality manuscripts appearing in the literature and the recent development of GEOBIA-related (open source/commercial) software packages. Towards that end, the bi-annual GEOBIA conferences held in Salzburg (2006), Calgary (2008), Ghent (2010), Rio de Janeiro (2012) and Thessaloniki, Greece (2014), have provided the impetus for much progress in Geographic Object-Based Image Analysis.

Specifically, this special issue aims to bring together articles that report advances and set up new perspectives in GEOBIA theory, methods and innovative applications including but not limited to the following:

- Image segmentation algorithms
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Please submit your manuscript by email directly to the Guest Editor:

Dr. Ioannis Z. Gitas
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Mapping India on Large Scales - A Quick and Viable Solution

Krishna Kumar Naithani

Abstract

For most of the mapping and engineering survey projects, the heights are still required above Mean Sea Level (MSL), whereas the heights given by Global Positioning System (GPS) are in terms of the WGS84 ellipsoid. The heights above MSL are called Orthometric Heights. Presently for India and many other countries, who have not yet established their own geoid, there is no method to convert the ellipsoidal heights to Orthometric heights. For such countries, the only way available to obtain Orthometric heights is through establishing a dense network of leveling lines that is very time consuming, cumbersome, and manpower- and cost-intensive. An alternative solution has been proposed that requires only a very few ground control points to be provided by GPS and a skeletal leveling network for large scale photogrammetric mapping without compromising accuracy. The concept has been validated with the aid of two test areas. It is shown that by adopting the proposed method, there is a significant reduction in the required number of GPS control points by more than 55 percent and the number of MSL height control points (as also the preprocessing/postpointing effort) by as much as 90 percent.

Introduction

India was one among the very few countries (including the advanced ones) to have completed topographic mapping on 1:50 000 and 1:25 000 scales, employing photogrammetric techniques, about four decades ago. Since then, there has been tremendous progress in the field of imaging and geomatics by way of the Global Positioning System (GPS), Inertial Measuring Units (IMUs), Large-Format High-Resolution Aerial Digital cameras, etc. Due to these developments, several countries have standardized the scales as large as 1:2500 and 1:1250 for country-wide topographic mapping and even larger scales ranging from 1:240 to 1:1200 for engineering applications mainly due to operability of GPS, IMU, and digital cameras which resulted in nearly complete automation for various photogrammetric processes, i.e., aerial triangulation, Digital Terrain Models (DTM), orthophoto generation, etc. The main advantage accrued due to these advancements is that there is a very little requirement of plan as well as vertical height ground control points (GCPs) for photogrammetric aerial triangulation (AT).

It is well established that with aerial imagery flown with GPS/IMU for photogrammetric applications, GCPs are required only at the corners of the photogrammetric block. Whereas, if aerial imagery is flown without GPS/IMU, full control points are required at close intervals along the periphery of the block, and height control points at much closer intervals in every flight line.

The provision of control points along with ellipsoidal heights is an easy task, because these can expeditiously be established with the help of GPS. But height control points, also known as Bench Marks (BMs), are invariably required with heights above Mean Sea Level (MSL), and therefore, cannot be determined by GPS.

Specifically in countries such as India who have not yet established their own geoid, the only method available to determine the heights above MSL, known as Orthometric heights, is by precision leveling which is cumbersome, slow, costly, and error-prone. Some countries like the US and Canada have established their own precise geoid along with a correction surface and have made the solution available to the public for conversion of GPS (ellipsoidal) heights to Orthometric heights. The correction surface is generated from a sufficiently dense network of GPS control points and height BMs established by precise leveling.

The Geomatics Center Canada provides an on-line facility for direct transformation of NAD83 or ITRF ellipsoidal heights of any point in the Canadian Territory to CGVD28 Orthometric heights, (CSRS-A). The National Geodetic Survey (NOAA) of the US has released the GEOID96 (recently upgraded to GEOID12A) hybrid Height Model for Conversion of GPS Heights to NAVD88 Orthometric elevations (Milbert and Smith, 1996). Facilities are available online for interactive computation of Orthometric heights from GPS ellipsoidal heights, i.e., the NGS Geodetic Tool Kit. Because of these resources, these countries are able to take full advantage of the recent developments and carry out large-scale photogrammetric mapping most economically in a much smaller time-frame as compared to others who do not have such a capability.

India is one among such countries who have not yet established a precise geoid along with the required correction surface. As a result, though India has the capability of acquiring aerial imagery employing most-modern digital cameras equipped with GPS/IMU, the requirement of plan and height control points for photogrammetric surveys is the same as was obtaining during the analogue era. The net result is that photogrammetric mapping, even on scale as small as 1:10 000, is not viable due to its demanding time and cost implications.

An interim solution, especially for such countries, is proposed in this paper to make the large scale photogrammetric mapping viable which takes maximum possible advantage of the current advances in the field of Geomatics.

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Nested Regression Based Optimal Selection (NRBOS) of Rational Polynomial Coefficients

Long Tengfei, Jiao Weili, and He Guojin

Abstract

Although the rational function model (RFM) is widely applied in photogrammetry, the application of terrain-dependent RFM is limited because of the requirement for numerous ground control points (GCPs) and the strong correlation between the coefficients. A new method, NRBOS, based on nested regression was proposed to select the optimal RPCs automatically and to gain stable solutions of terrain-dependent RFM using a small amount of GCPs. Different types of images, including QuickBird, SPOT5, Landsat-5, and ALOS, were involved in the tests. NRBOS method performed better than conventional methods in estimating RPCs, and even provided a reliable solution when less than 39 GCPs were used. Additionally, the test results showed that the simplified RPCs are almost as accurate as the vendor-provided RPCs. Consequently, in favorable situations such as when the orientation parameters of the satellite are not available or are not sufficiently accurate, the proposed method has the potential to take the place of the regular terrain-independent RFM.

Introduction

The rational function model (RFM) with 78 rational polynomial coefficients (RPCs) is completely a mathematical model, which approximately describes the imaging process in photogrammetry and remote sensing. Terrain-independent RFM constitutes a comprehensive reparameterization of the rigorous sensor model, and is widely applied in high resolution image products. Terrain-dependent RFM, on the other hand, is hardly used because of the requirement for numerous observation data (ground control points (GCPs)), and the strong correlation between the coefficients. Actually, terrain-dependent RFM provides a useful approach to rectify remotely sensed images without knowing the position and orientation information of specific sensor. However, as 78 RPCs of the RFM are strongly correlated, stable, and precise solutions of the RPCs are difficult or even impossible to achieve (Lin and Yuan, 2008). The objectives of this research are to find a robust approach to estimate RPCs and to make use of the terrain-dependent RFM.

Many studies have been carried out on the topic of RFM during the recent decades. OGC (1999) has normalized the range of the image and object space coordinates of RFM to −1 to +1, and effectively enhanced the condition number of the normal equation matrix. Tao and Hu (2000) have studied the RFM comprehensively and have proposed to strengthen the solution of RFM using Tikhonov regularization and the L-curve method. Yuan and Lin (2008) have compared the results of several methods for solving RPCs including ridge trace method, L-curve method, empirical formula method, and generalized ridge estimate method; they have verified the validity of L-curve method. In addition, Levenberg-Marquardt method (Tao and Hu, 2001) and singular value decomposition method have been applied to solve RPCs (Fraser *et al.*, 2006). Among all these methods, the ridge estimation method (especially the L-curve method) is the most widely used approach. However, there are still some problems in solving RPCs using the existing methods. For example, ridge estimate is a biased estimate, which requires numerous GCPs to solve RPCs.

Solving RPCs is a problem of multiple regression analysis. The problem of multicollinearity results in an ill-posed normal equation, and the ordinary least squares (OLS) estimation does badly in achieving a stable and reliable solution. In order to solve the problem of multicollinearity, "variable selection (Draper *et al.*, 1966)" and "ridge estimation (Hoerl and Kennard, 1970)" are usually used to improve the OLS. Variable selection can simplify the original model by selecting a subset of variables from the original set of variables which give the most significant response to the regression, and therefore the multicollinearity of the model can be reduced after the variable selection (Guyon and Elisseeff, 2003). Both of the two methods have drawbacks. Variable selection provides interpretable model but can be extremely variable because it is a discrete process. Ridge regression is a continuous process that shrinks coefficients and hence is more stable. However, it does not set any coefficients to 0 and hence does not give an easily interpretable model (Tibshirani, 1996). In addition to the methods mentioned above, in statistics, some improvements of ridge estimation method (Bashtian *et al.*, 2011; Jurczyk, 2012; Kibria and Saleh, 2012; Park and Yoon, 2011) have been proposed in recent years. However, they still need a large number of observation data.

Variable selection is a non-deterministic polynomial (NP) problem whose search space is very large (Amaldi and Kann, 1998). During the past decades, hundreds of methods have been proposed to solve this problem, including genetic prediction, decision tree prediction, Bayes prediction, least square prediction, and support vector machine prediction (Guyon and Elisseeff, 2003), and all these methods need a huge computation. Greedy search strategy can greatly reduce the search space and thus improve the efficiency of the algorithm. The greedy search methods are mainly divided into three categories: forward selection, backward elimination, and stepwise regression analysis. Nonetheless, there are common disadvantages in these methods. Not all the possible combinations of variables are taken into account, and the results which greatly depend on the evaluation criterion are usually not the optimal solution. In addition, the variable transformation, such as principal component analysis, partial least

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A Statistical Model Inspired by the National Map Accuracy Standard

F.J. Ariza-López and J. Rodríguez-Avi

Abstract
This work proposes a statistical model inspired by the National Map Accuracy Standard pass/fail philosophy. The model is formulated as the composition of a statistical Binomial model on other statistical base models (parametric or nonparametric). This formulation allows adapting of the pass/fail philosophy of the NMAS *to any desired statistical base model, tolerance, percentage of points in error, and risks. The main contribution of this proposal is a common framework for dealing with sampling and risks with independence of the underlying base model (parametric or nonparametric). The use of nonparametric base models is explained and exemplified for the 1D case. For 2D and 3D, the Gaussian base model has been adopted. The Gaussian models allow the combining of error components by means of the Chi Squared and the Gamma distributions. For the 2D case, different situations have been considered in order to analyze the pass/fail behavior, and producer's and user's risks.*

Introduction
The positional accuracy of geospatial products has always been of great importance. This is, together with logical consistency, the quality element of geographic information most extensively used by the National Mapping Agencies (NMA), and also the more commonly evaluated quality element option (Jakobsson and Vauglin, 2002). Positional accuracy is a matter of renewed interest because of the capabilities offered by the Global Navigation Satellite System (GNSS) and the need of a greater spatial interoperability for supporting the Spatial Data Infrastructures. Different positional behaviors of geographic data sets mean the existence of an inter-product positional distortion and a barrier to interoperation (Church *et al.*, 1998). This barrier exists not only for the positional and geometric aspects, but also for thematic ones which are greatly affected by position (Carmel *et al.*, 2006). For these reasons many NMAS are currently involved in the development of positional accuracy improvement programs (EuroSDR, 2004).

In a Spatial Data Set (SDS) the position of a real world entity is described with values in an appropriate coordinate system. Positional accuracy represents the nearness of those values to the entity's "true" position in that system. The positional accuracy requirements for an SDS are directly related to its intended use(s). Positional accuracy is determined by means of a statistical evaluation of random and systematic errors (DOD, 1990) and specified by means of the Root Mean Squared Error (RMSE) or by the mean value of errors (μ) and their standard deviation (σ). Comparison with an independent source of greater accuracy is the preferred method for assessing positional accuracy (ANSI, 1998).

Since positional accuracy is essential in geospatial production, all NMAS have used statistical methods for its control, which we call here Positional Accuracy Assessment Methodologies (PAAMs). Many of these have been established as national or international standards and can be used for specifying spatial data products but also the resultant positional accuracy assessment compliance criteria. Standards should be taken into account when seeking an economic optimization of the quality of geographic information (Krek and Frank, 1999): with a quality standard the producer provides the product according to the known specification and characteristics, as defined in the standard. This assures a certain level of reliability and certainty, allowing the acquirer to avoid excessive measuring of the quality and thus reducing the measuring cost and shortening the decision-making process.

The International Organization for Standardization (ISO) considers positional accuracy to be one of the quantitative quality elements of geographic information as stated in its international standard 19157 (ISO 2012), which is a general framework for describing and reporting the quality of geographic information. This International Standard also proposes a general quality evaluation methodology for geographic information which must be applied to all the quality elements of geographic information (e.g., position, completeness, consistence, thematic accuracy, and so on). This standard is a generic guideline, and there is no specific or preferred method for positional quality assessment. Because this International Standard is a general framework, there is a need to clearly define aspects such as the computation of errors, sample size, and schema, acceptation/rejection criteria, and so on. We believe that the future of positional accuracy assessment must be resolved within ISO standards, but prior to this we need to know about current methods and their improvement possibilities in order to develop appropriate assessment methods for the positional aspect of geographic information.

This work is about the National Map Accuracy Standard (NMAS) (USBB, 1947), a standard of very simple application and broadly used in the entire world from its publication date. We propose a statistical formulation based on well-known statistical models, and given the current interest in controlling 3D positional accuracy (e.g., Cai and Rasdorf, 2009; Li *et al.* 2009), our proposal incorporates the third dimension as a logical extension of the 2D model. We also develop a 1D non-parametric case. The interest of our approach is twofold: first it can be used to better understand past re-

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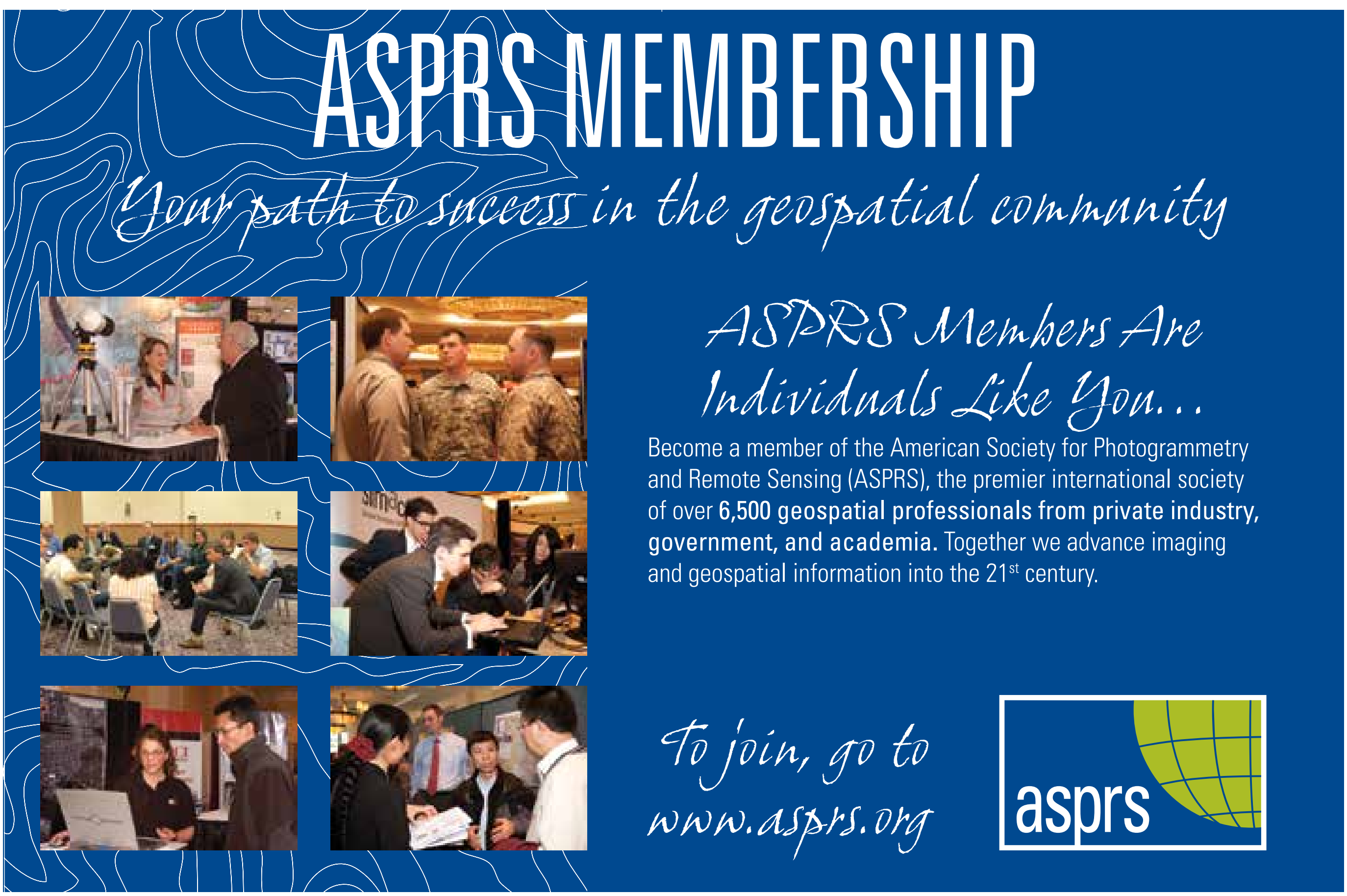

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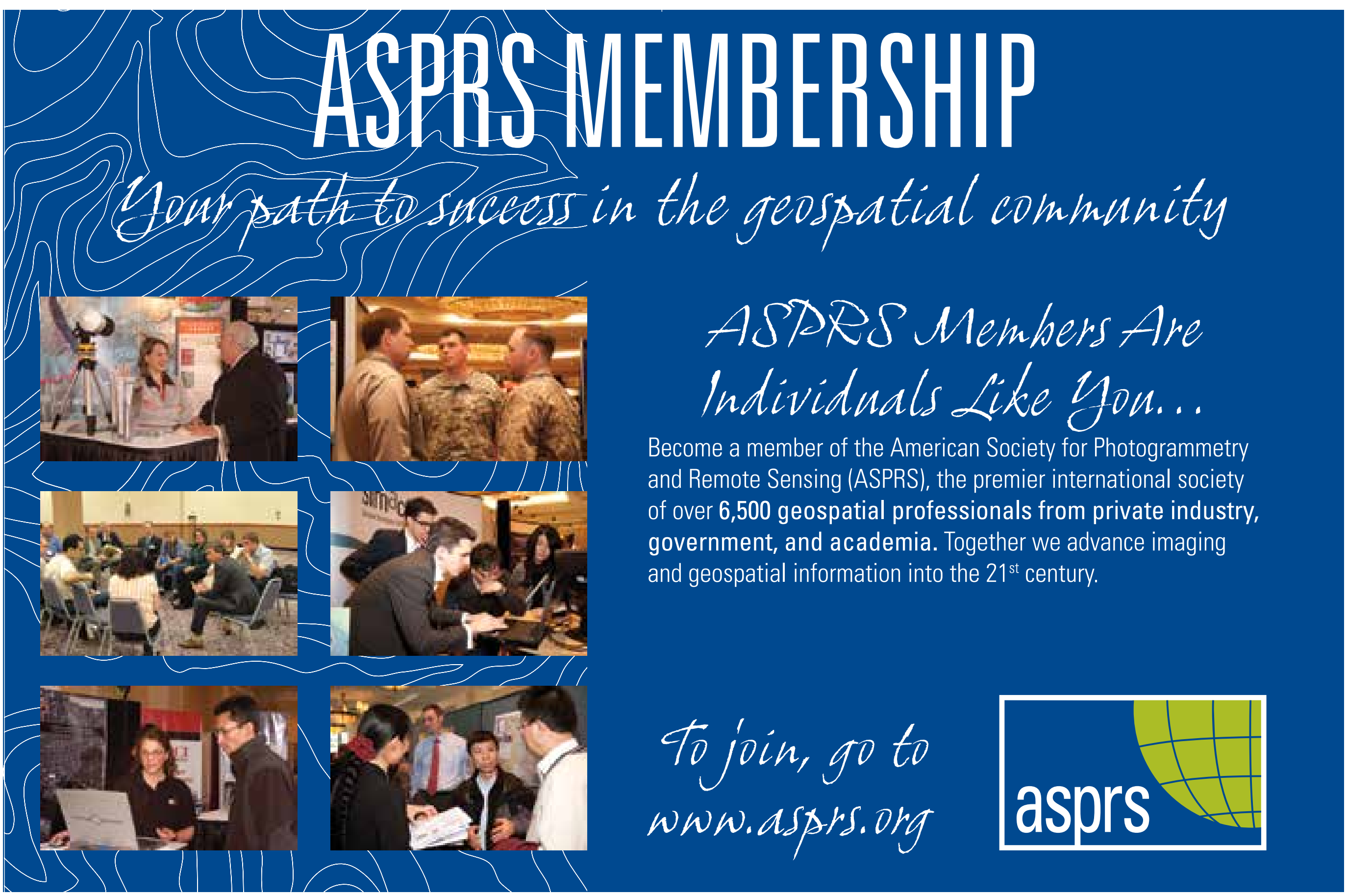

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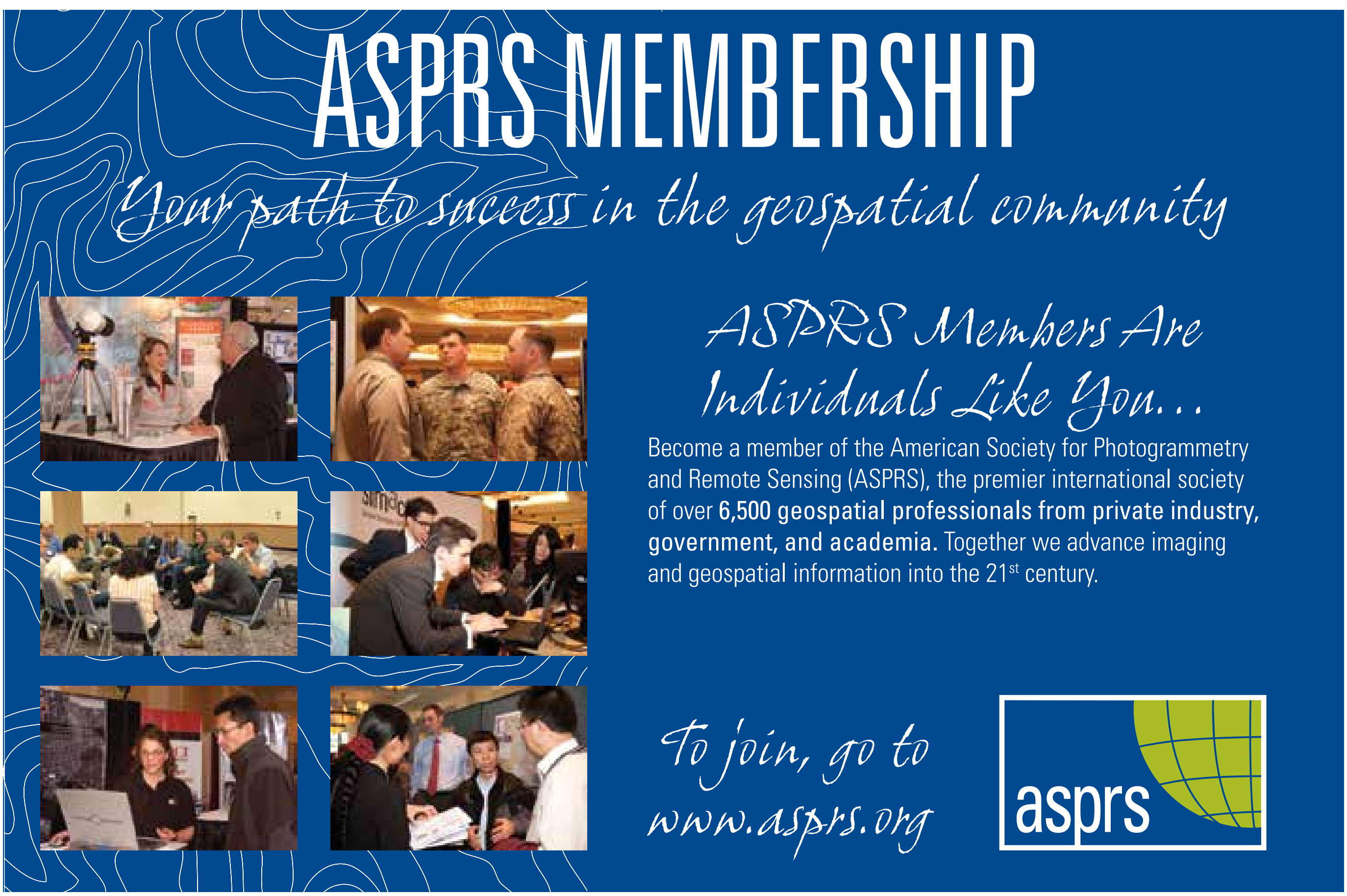

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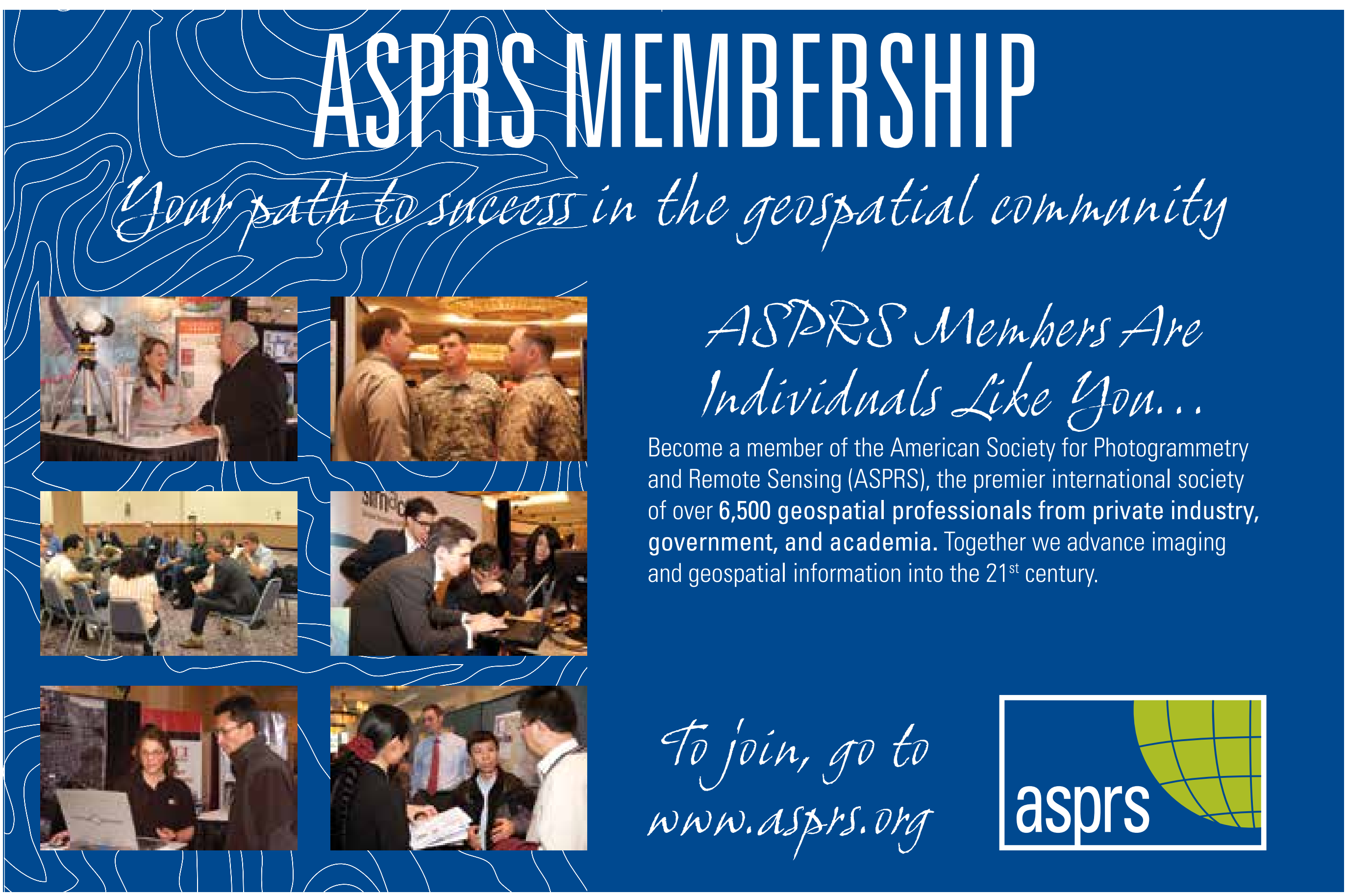

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Journal Articles:
Meyer, M.P., 1982. Place of small-format aerial photography in resource surveys, *Journal of Forestry*, 80(1):15-17.

Proceedings (printed):
Davidson, J.M., D.M. Rizzo, M. Garbelotto, S. Tjosvold, and G.W. Slaughter, 2002. Phytophthora ramorum and sudden oak death in California: II. Transmission and survival, *Proceedings of the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape*, 23-25 October 2001, San Diego, California (USDA Forest Service, General Technical Report PSW-GTR-184, Pacific Southwest Forest and Range Experiment Station, Berkeley, California), pp. 741-749.

Proceedings (CD-ROM):
Cook, J.D., and L.D. Ferdinand, 2001. Geometric fidelity of Ikonos imagery, *Proceedings of the ASPRS 2001 Annual Convention*, 23-27 April, St. Louis, Missouri (American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland), unpaginated CD-ROM.

Thesis and Dissertations:
Yang, W., 1997. *Effects of Spatial Resolution and Landscape Structure on Land Cover Characterization*, Ph.D. dissertation, University of Nebraska-Lincoln, Lincoln, Nebraska, 336 p.

Website References:
Diaz, H.F., 1997. Precipitation trends and water consumption in the southwestern United States, USGS Web Conference, URL: http://geochange.er.usgs.gov/sw/changes/natural/diaz/, U.S. Geological Survey, Reston, Virginia (last date accessed: 15 May 2002).

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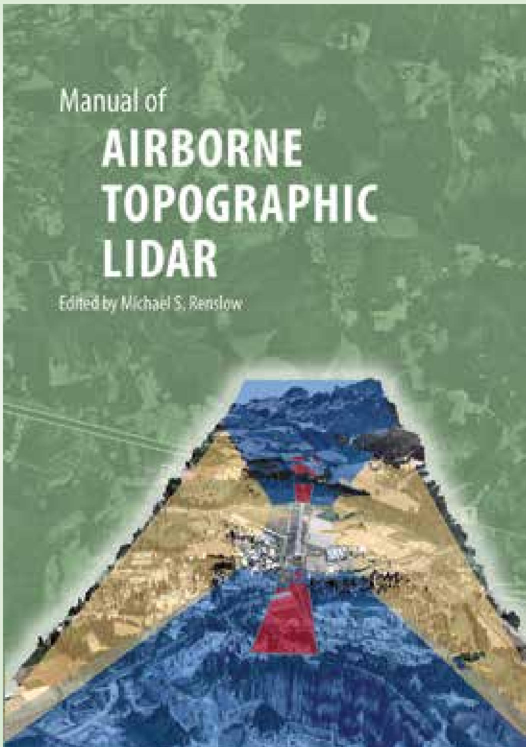
Manual of Airborne Topographic Lidar

Edited by Michael S. Renslow



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