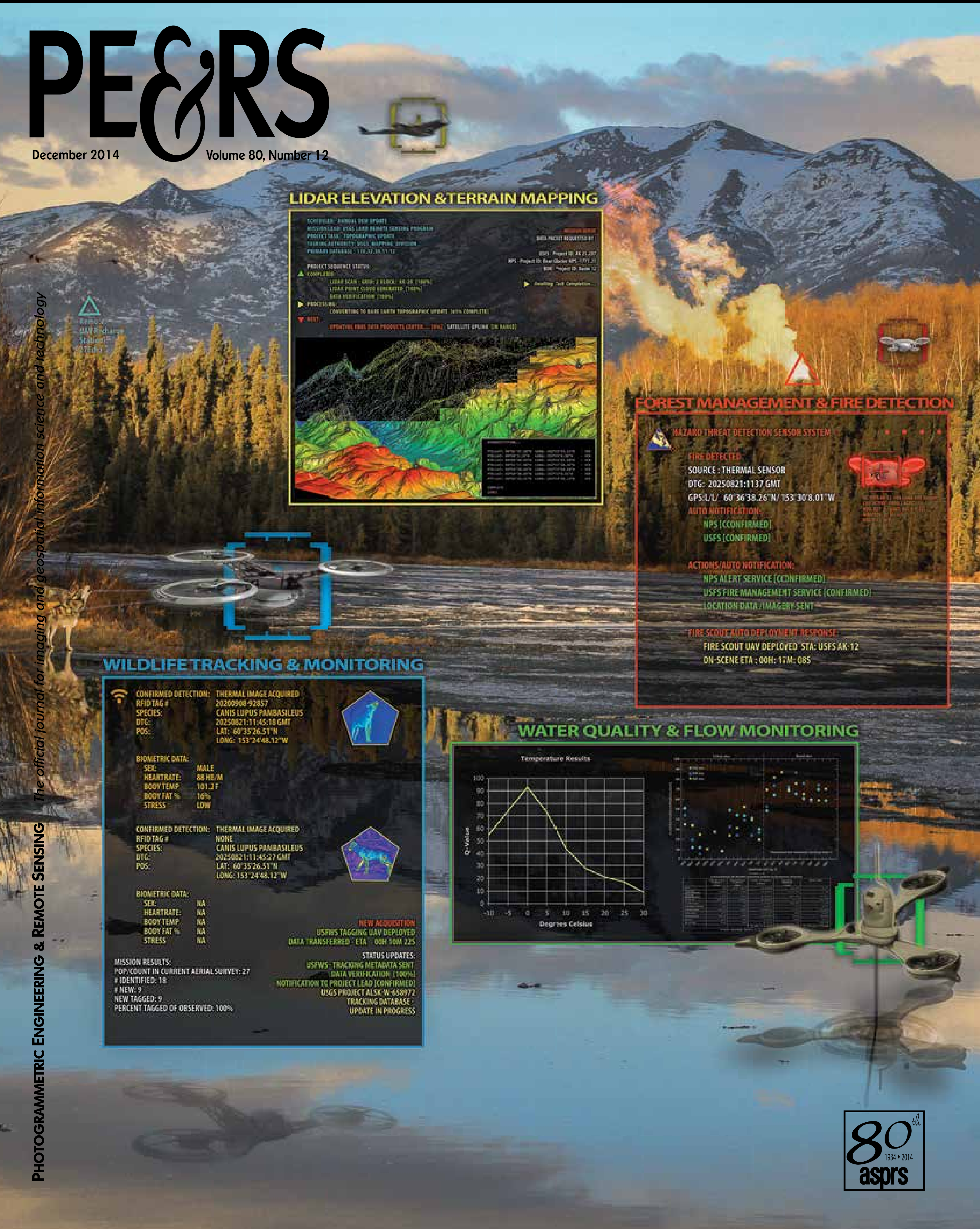
Special Issue: Advances in Unmanned Aircraft Systems Technology and Applications

PE&RS

December 2014 Volume 80, Number 12

Photogrammetric Engineering & Remote Sensing *The official journal for imaging and geospatial information science and technology*



80th 1934 • 2014 asprs

INTRODUCING THE ASPRS SMARTPHONE APP

asprs THE IMAGING & GEOSPATIAL INFORMATION SOCIETY

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.

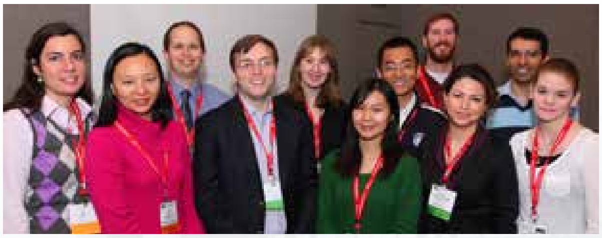
Downloading the new ASPRS app is simple! iPhone users can visit the Apple App Store and download the ASPRS App free of charge. Android users may access via the Google Plays Store to download the new version, also free of charge. Individuals may also find the links to download the smartphone app on the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

Download on the App Store

GET IT ON Google play

Save the Date!
ASPRS 2015 Annual Conference
Tampa Bay Marriott Waterside Hotel
Tampa, Florida
May 4-8, 2015
asprs
THE IMAGING & GEOSPATIAL INFORMATION SOCIETY

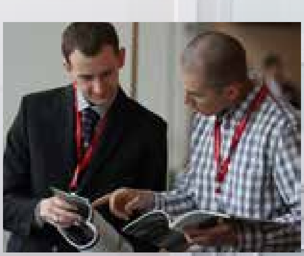
The ASPRS Student Advisory Council (SAC) ...
...ensuring Student Member representation in ASPRS and more.



SAC is a group of students committed to serving all of the student members of ASPRS. Our goal is to ensure that ASPRS is a Society that both benefits from student involvement and creates opportunities for those students.

SAC is led by a Council of seven students who meet monthly to discuss issues pertaining to ASPRS Student Members. What do they do?

- **Organize special sessions** of interest to students at ASPRS Annual and fall conferences. http://www.asprs.org/Annual-Conferences/Program/
- **Create networking opportunities** during those conferences and bring together students looking for employment after graduation with potential employers in the industry.
- Inaugurate new programs within ASPRS.
- Design activities such as the **GeoLeague Competition** where students compete in teams using geospatial technology applications to solve a problem. http://www.asprs.org/Students/GeoLeague-Challenge-2014.html.



Promote student involvement in humanitarian projects such as crowdsourcing the manual interpretation of imagery in Somalia to identify shelters that are being used as homes by refugees. http://irevolution.net/tag/tomnod/.

All ASPRS Student Members are encouraged to become involved with SAC. Check out the SAC Social Networking sites and keep up with ongoing news.

Student Newsletter: http://asprssignature.blogspot.com/

Facebook page: https://www.facebook.com/pages/ASPRS-Student-Advisory-Council/117943608233122

LinkedIn Group: http://www.linkedin.com/groups?home=&gid=2487675&trk=anet_ug_hm

Email: asprs.chairsac@gmail.com

asprs STUDENT ADVISORY COUNCIL THE IMAGING & GEOSPATIAL INFORMATION SOCIETY

PE&RS

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

The official journal for imaging and geospatial information science and technology

December 2014 Volume 80 Number 12

COLUMNS

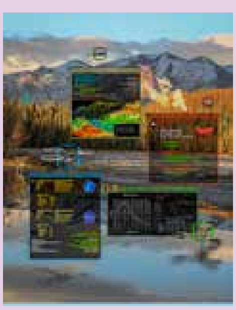
Letter from Rae Kelley, ASPRS Assistant Director—Publications **1088**
Grids and Datums—*Republic of Tajikistan* **1099**
Behind the Scenes **1101**
Book Review—*Advances in Mapping from Remote Sensor Imagery: Techniques and Applications* **1103**

ANNOUNCEMENTS

ASPRS 2015 Annual Conference **1085, 1105**
Call for Papers **1106**
ASPRS Code of Ethics **1138**

DEPARTMENTS

Region News **1098**
Certification **1100**
Industry News **1100**
ASPRS News **1104**
New Members **1104**
Calendar **1116**
Forthcoming Articles **1116**
Who's Who in ASPRS **1170**
Sustaining Members **1171**
Instructions for Authors **1173**
Membership Application **1176**



Advances in Unmanned Aircraft Systems Technology and Applications is the focus of this *PE&RS* special issue. Successful military application of Unmanned Aircraft Systems (UAS) technology to perform intelligence, surveillance and reconnaissance has ignited the interest of the civil, commercial and academic remote sensing communities in the research and operational applications of these technologies. This special issue of *PE&RS* focuses on UAS technology and the current and future applications of UAS. The cover represents a possible future scenario where multiple UAS acquire different types of data through different sensors – one UAS performs terrain mapping with a lidar sensor, another is collecting forestry data and also detects a fire, the third is gathering water quality and flow information and the final UAS is monitoring wildlife. These data can be shared and integrated with other geospatial data to answer many types of scientific inquiries.

HIGHLIGHT ARTICLE

1089 Unmanned Aircraft Systems (UAS) Activities at the Department of the Interior

Bruce K. Quirk and *Michael E. Hutt*

PROFESSIONAL INSIGHT—AN INTERVIEW

1096 USS (Unmanned Santa Systems) Excitement and Controversy at the North Pole

PEER-REVIEWED ARTICLES

1107 GPU Processing for UAS-Based LFM-CW Stripmap SAR

Craig Stringham and *David G. Long*

The development of a stripmap SAR backprojection processor that addresses the geometries and motion typical of UAS-based SAR systems and achieves real-time processing using a GPU.

1117 Feasibility Study for Pose Estimation of Small UAS in Known 3D Environment Using Geometric Hashing

Julien Li-Chee-Ming and *Costas Armenakis*

A novel localization approach for small unmanned aerial systems in urban areas based on matching video images with 3D models.

1129 Multi-UAV Surveillance over Forested Regions

Vengatesan Govindaraju, Gerard Leng, and *Zhang Qian*

A novel method to determine the near-optimal flight paths for Multiple UAVs to conduct an effective surveillance over forested regions, using the DEM and land cover information.

1139 Retrieval of Spectral Reflectance of High Resolution Multispectral Imagery Acquired with an Autonomous Unmanned Aerial Vehicle: AggieAir™

Bushra Zaman, Austin Jensen, Shannon R. Clemens, and *Mac McKee*

Spectral reflectance retrieval of UAV AggieAir™ imagery.

1151 Modeling Above-Ground Biomass in Tallgrass Prairie Using Ultra-High Spatial Resolution sUAS Imagery

Chuyuan Wang, Kevin P. Price, Deon van der Merwe, Nan An, and *Huan Wang*

Modeling and predicting tallgrass above-ground biomass can be accomplished using ultra-high spatial resolution imagery collected by small unmanned aircraft systems.

1161 High Resolution Imagery Collection for Post-Disaster Studies Utilizing Unmanned Aircraft Systems (UAS)

APPLICATIONS PAPER

Stuart M. Adams, Marc L. Levitan, and *Carol J. Friedland*

Review and case study of unmanned aircraft systems (UAS) usage for high resolution imagery collection for post-disaster studies.

LETTER FROM RAE KELLEY, ASPRS ASSISTANT DIRECTOR—PUBLICATIONS

Thank you!

2014 has been a year of challenges for ASPRS and *PE&RS;* new leadership and the sudden death of Kim Tilley, Associate Executive Director and Director of Communications, we've gone through a lot of changes. We are making a comeback!

The ASPRS Staff is working hard to make ASPRS a member centric organization with changes to most of our programs and *PE&RS*. Throughout 2014, we've introduced several new columns and features, and added material that is relevant and timely for our readers.

- The Opening Letter – highlights an article in the Journal or news at Headquarters.
- Professional Insight – interviews with industry professionals whom have interesting industry experiences to share.
- Behind the Scenes – this is our new technology column. It gives us a technical look inside the present and future of geospatial and imaging technologies.
- Region News – highlights the activities of ASPRS regions. Check in and see what special events regions are holding throughout the US!
- Industry Insight – we welcome your opinions on the redesign of *PE&RS*, the new articles, and columns. Industry Insight is where we publish your "letters to the editor".

This is your organization and your Journal. We want to make sure the articles and columns cover a wide variety of information specific to the industry and cover ideas suitable for your career. We also would like to hear from you. Tell us your thoughts, give us your ideas! How can ASPRS and *PE&RS* better fit your needs?

Again, thank you for sticking with us during this challenging year.

Things are changing…experience the new, refreshed and revised!

Rae Kelley
Assistant Director— Publications

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING

THE IMAGING & GEOSPATIAL INFORMATION SOCIETY

Photogrammetric Engineering & Remote Sensing is the official journal of the American Society for Photogrammetry and Remote Sensing. It is devoted to the exchange of ideas and information about the applications of photogrammetry, remote sensing, and geographic information systems. The technical activities of the Society are conducted through the following Technical Divisions: Geographic Information Systems, Photogrammetric Applications, Lidar, Primary Data Acquisition, Professional Practice, and Remote Sensing Applications. Additional information on the functioning of the Technical Divisions and the Society can be found in the Yearbook issue of *PE&RS*.

Correspondence relating to all business and editorial matters pertaining to this and other Society publications should be directed to the American Society for Photogrammetry and Remote Sensing, 5410 Grosvenor Lane, Suite 210, Bethesda, Maryland 20814-2144, including inquiries, memberships, subscriptions, changes in address, manuscripts for publication, advertising, back issues, and publications. The telephone number of the Society Headquarters is 301-493-0290; the fax number is 301-493-0208; web address is www.asprs.org.

PE&RS. *PE&RS* (ISSN0099-1112) is published monthly by the American Society for Photogrammetry and Remote Sensing, 5410 Grosvenor Lane, Suite 210, Bethesda, Maryland 20814-2144. Periodicals postage paid at Bethesda, Maryland and at additional mailing offices.

SUBSCRIPTION. For the 2014 subscription year, ASPRS is offering two options to our *PE&RS* subscribers -- an e-Subscription and the print edition. E-subscribers can plus-up their subscriptions with printed copies for a small additional charge. Print subscriptions are on a calendar-year basis that runs from January through December. Electronic subscriptions run for twelve months on an anniversary basis. We recommend that customers who choose both e-Subscription and print (e-Subscription + Print) renew on a calendar-year basis. The new electronic subscription includes access to ten years' of digital back issues of *PE&RS* for online subscribers through the same portal at no additional charge. Please see the Frequently Asked Questions about our journal subscriptions.

The rate of the e-Subscription (digital) Site License Only for USA and Foreign: $2000; e-Subscription (digital) Site License Only for Canada*: $2100; **Special Offers:** e-Subscription (digital) Plus Print for the USA: $2,160; e-Subscription (digital) Plus Print Canada*: $2,273.25; e-Subscription (digital) Plus Print Outside of the USA: $2,175; Printed-Subscription Only for USA: $660; Printed-Subscription Only for Canada*: $762; Printed-Subscription Only for Other Foreign: $735. *Note: e-Subscription/Printed-Subscription Only/e-Subscription Plus Print for Canada include 5% of the total amount for Canada's Goods and Services Tax (GST #135123065).

POSTMASTER. Send address changes to *PE&RS*, ASPRS Headquarters, 5410 Grosvenor Lane, Suite 210, Bethesda, Maryland 20814-2144. CDN CPM #(40020812)

MEMBERSHIP. Membership is open to any person actively engaged in the practice of photogrammetry, photointerpretation, remote sensing and geographic information systems; or who by means of education or profession is interested in the application or development of these arts and sciences. Membership is for one year, with renewal based on the anniversary date of the month joined. Membership Dues include a 12-month subscription to *PE&RS*. Subscription is part of membership benefits and cannot be deducted from annual dues. Beginning with the January 2014 issue of *PE&RS*, all members outside of the USA will receive access to the full digital edition of the journal rather than the printed copy. Dues for ASPRS Members outside of the U.S. will now be the same as for members residing in the U.S. Annual dues for Regular members (Active Member) is $150; for Student members it is $50 for USA and Canada; $60 for Other Foreign (E-Journal – No hard copy for all Students); for Associate Members it is $100 (member must be under the age of 35, see description on application in the back of this Journal). A tax of 5% for Canada's Goods and Service Tax (GST #135123065) is applied to all members residing in Canada

Unmanned Aircraft Systems (UAS) Activities at the Department of the Interior

By Bruce K. Quirk and Michael E. Hutt

Introduction

The U.S. Department of the Interior (DOI) is responsible for protecting and managing the natural resources and heritage on almost 20% of the land in the United States. The DOI's mission requires access to remotely sensed data over vast lands, including areas that are remote and potentially dangerous to access. The challenges associated with meeting this requirement for scientific data and information about our public lands, their ecosystems, and natural resources have produced many innovative remote sensing strategies. Although DOI scientists can obtain very accurate *in situ* data based on ground measurements and sample collections, the scale of public lands makes this approach unrealistic for a large area or periodic surveys. Sensors aboard piloted aircraft can, and frequently do, provide large area coverage with high-resolution data. But increasing costs and potential safety issues, such as pilot physiology, can limit their availability. The fact that many of these manned aircraft flights must take place in areas that can be remote and often dangerous to access, like the north slope of Alaska or the Everglades, only increases these concerns. Also, manned aircraft flights may not be feasible due to the necessity for low-altitude flying and hazardous weather conditions. Although satellite data have proven to be a vital resource through the Landsat and other earth observation missions, they have limitations related to spatial and spectral resolutions, weather conditions, and acquisition timeframes due to orbital dependencies. In response to these ongoing data collection challenges it is crucial for the DOI to continually evaluate new technologies with an emphasis on finding safer, lower cost, and more flexible methods for collecting remotely sensed data.

One promising new technology for acquiring these vital data is Unmanned Aircraft Systems (UAS). UAS have often been described as the ideal solution for airborne missions characterized as "dull, dirty, or dangerous" because they operate as an aircraft, but without a human pilot on board. Their flight is controlled autonomously, by computer, or under the remote control of a pilot on the ground. UAS also come in a variety of shapes, sizes, and configurations to support a wide variety of sensor packages, which allows them to provide maximum flexibility for remote sensing data collection. DOI missions requiring patrol of vast expanses of public lands, monitoring of natural resources (land, water, and air), and remote sensing over rugged terrain could benefit from this technology. In addition to supporting safer missions over rugged terrain, operation of UAS, particularly small UAS (sUAS), have also proven to be much more cost effective than manned missions based on initial studies. UAS provide scientists a way to look longer, closer, and more frequently at remote areas where, in the past, it would be too dangerous or too expensive to monitor and without disturbing the environment they are observing. UAS can provide data in real-time and permit data acquisition under marginal weather conditions (acquisition under clouds), which results in better science, safer acquisition of data and at a savings over conventional remote sensing techniques. The flexibility of operations and relatively low-cost of UAS make them an ideal platform for acquiring remote sensing data in many situations (OpusTek International Corporation, 2011).

Figure 1. Launching the Raven during a mission in the Haleakala National Park, Maui, Hawaii (USGS).

Background

The DOI first used UAS technology in 2004 to acquire data during a volcanic event on Mount Saint Helens (Patterson *et al.,* 2005). This successful mission demonstrated that UAS technology had matured enough for it to possibly become a cost-effective remote sensing tool for scientific, environmental and land management applications. To further investigate this possibility the U.S. Geological Survey (USGS) Land Remote Sensing Program sponsored a 2005 emerging technology investigation of UAS technology, which resulted in findings that UAS technology was developing at a rapid rate; many civil agencies were establishing UAS Program Offices, numerous U.S. universities were offering UAS programs, and the number of UAS vendors were quickly increasing. This evaluation concluded that UAS technology had started to transition towards a mainstream technology that could be used as a new remote sensing tool for the DOI.

The USGS National UAS Project Office (NUPO), located in Denver Colorado, was created on May 2008 as a next step towards evaluating the operational use of UAS technology in the DOI. The NUPO was designed to lead and coordinate efforts to implement UAS technology as a cost-effective option for acquiring remotely sensed data within the USGS and across the DOI.

The DOI has already made significant progress towards implementation of a cost-effective UAS operational capability. One of the first steps was the establishment of an organizational framework within the DOI, consisting of the Department's Office of Aviation Services (OAS) and the newly created USGS NUPO, tasked with focusing on UAS evaluations and development of an operational strategy. Early accomplishments included establishing training requirements, creating a cadre of certified UAS operators, and a partnership with the U.S. Army resulting in access to a fleet of Raven sUAS (Figure 1). This allowed even more rapid progress, with proof of concept missions that supported the development and testing of approval procedures, operational processes, and cost benefit information (Department of the Interior, 2013).

UAS Strategy

A comprehensive UAS strategy has been developed that is tailored to the mission, funding, personnel, and infrastructure levels of the DOI and includes:

- Focusing on sUAS, which are more aligned with DOI's decentralized mission execution strategy and more supportable by the Department's funding, personnel and infrastructure levels.
- Leveraging available excess DOD sUAS to minimize procurement, training, and support costs.
- Establishing partnerships with Federal agencies and universities that possess UAS capabilities beyond DOI's to support DOI missions, avoid duplication, share missions and enhance capabilities.
- Conducting operational tests and evaluations of various UAS technologies to support the development of long-range UAS requirements and strategy.

Based on the requirements and strategy developed above, the DOI can procure (buy or contract) sUAS capabilities that cannot be met either through excess DOD sUAS or those available through partnerships with other organizations, including service contracts with the commercial sector that would provide the required data sets.

Privacy

The DOI has decades of proven experience in the proper collection, use, control, and retention of aerial and satellite data, and employs the same policies for its UAS data sets.

Although UAS are starting to prove their effectiveness, recent concerns with the potential of UAS to infringe on an individual's right to privacy threaten to overshadow the benefits this technology promises to bring to the DOI's mission. Consequently, privacy concerns must be addressed effectively if a DOI bureau expects the public to continue their support of the use of UAS, especially since the potential for more routine use could increase privacy concerns.

All DOI UAS missions are in full compliance with Federal laws, and with DOI policies and procedures. The data collected with UAS sensors are handled and retained within industry standards, consistent with data collected with any of the DOI's remote sensing systems. The UAS missions are subject to professional standards, codes of conduct, and case law with the public's trust in mind.

Missions

Satellites, manned aircraft or *in situ* observations have traditionally collected data needed to meet the DOI's demand for remote sensing data, sometimes at a significant risk or cost. The leading cause of field biologist fatalities in the DOI from 1937 to 2000 was aviation related (Sasse, 2003). However, introducing a new technology can be challenging since it must not only be more cost effective than traditional methods, but must also meet any required data specifications, and be able to operate with minimal disruption to the environment and ecosystems being observed. The DOI, working with many partners, is actively conducting operational test and evaluations (OT&E) of UAS technology, which are designed to evaluate the potential of the technology to support mandated DOI scientific, resource and land management missions. Completed proof of concept UAS missions have been crucial in determining how the technology can cost effectively meet the DOI remote sensing data demand (Figure 2). These missions have been able to provide invaluable information on how to most efficiently implement this technology, but also provide insight into the associated costs. Execution of these missions has also provided a perfect opportunity to develop and test required operation-

"The DOI, working with many partners, is actively conducting operational test and evaluations (OT&E) of UAS technology."

Figure 2. Total number for flight hours of DOI operational and test evaluation missions from fiscal year 2010 to 2014 (USGS).

al procedures and processes. The DOI has collaborated with other Federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), universities, and private industry on many of these missions. Collaboration has been essential in the OT&E phase and has allowed evaluations of a wider range of UAS and sensors to meet DOI mission requirements.

Investigations performed during the execution of these proof of concept missions have been crucial in addressing many questions and concerns, and have clearly demonstrated that UAS can cost effectively meet scientist's requirements and provide safe, low risk support in areas such as wildlife management and environmental research.

Diverse Applications

UAS technology is being used by the DOI to monitor environmental conditions, analyze the impacts of climate change, respond to natural hazards, understand landscape change rates and consequences, conduct wildlife inventories and support related land management and law enforcement missions. The Department's field-level staff are driving the investigations of UAS technology. The innovation and dedication of DOI scientists and resource managers are apparent as they turn to UAS and associated remote sensing tools to perform traditional tasks more cheaply and create new uses for the technology. Wildlife biologists were the first to implement the technology (monitoring and inventorying wildlife), followed by hydrologists (monitoring shoreline erosion and stream temperature gradients), ecologists (habitat mapping), and geologists (landslide monitoring).

DOI's public safety professionals are interested in using UAS to support their activities, including search and rescue, monitoring pipelines and wildland firefighting. In general, if an observation can be obtained with a manned aircraft today, DOI is investigating doing it with a UAS in the future.

The underlying information technology to process, export and disseminate the UAS data is also being evaluated to meet the goal to efficiently processing these robust data sets into actionable information. Using a sUAS, the DOI is able to tailor solutions to meet project requirements and obtain very high-resolution video, acquire thermal imagery, detect chemical plumes, and collect point cloud data at a fraction of the cost of conventional surveying methods. UAS technology is allowing the DOI to do more with less and in the process enhance our ability to provide unbiased scientific information to better enable resource managers and policy makers to make informed decisions. The results of two of the many OT&E missions are provided below as examples of UAS technology benefiting the DOI mission.

Figure 3. Sandhill cranes (USGS).

Sandhill Crane Population Survey

One of the earliest UAS missions occurred during March 2011 at the Monte Vista National Wildlife Refuge (NWR) near Monte Vista, Colorado. This mission was performed in cooperation with the U.S. Fish and Wildlife Service (FWS) to study the feasibility of using UAS to survey Sandhill cranes (Figure 3). The FWS, mandated by the Migratory Bird Treaty Act, is responsible for performing periodic surveys of the Sandhill crane population. Sandhill cranes are migratory birds that travel from Texas to Idaho (or as far as Siberia) annually and the Monte

Vista NWR serves as a major stopover point during migration, which makes it a perfect location for conducting an accurate population count.

These surveys are traditionally conducted by using fixed-wing aircraft, which can place both birds and staff at risk of mid-air collisions, or time consuming ground-count methods, where biologists in the field attempt to visually enumerate the birds with sectional surveys. Safe completion of the UAS flights (Figure 4) clearly demonstrated that the DOI's sUAS could be flown without disruption to the cranes and that the sensor payloads could identify their heat signature.

Figure 4. Ground track for Raven aerial survey (USGS, FWS, Google).

The population count from the UAS data was compared to a simultaneous ground-count conducted by the FWS to get an "observed" population count. Results of the comparison between the ground based and UAS population counts resulted in a 4.6% difference, which was acceptable to the wildlife biologists. The cost of the UAS mission (<$3,000) was substantially less than the cost of a similar fixed wing manned aircraft survey (~$30,000). These results established that utilizing UAS to perform population counts for Sandhill cranes is both safe and cost effective, and produces accurate results.

Abandoned Solid Waste Removal

In March 2013, the USGS, in cooperation with the National Park Service (NPS) Mojave National Preserve, flew proof of concept sUAS missions to locate and survey abandoned solid waste for historical assessment potential and cleanup. The primary objective was to determine if sUAS technology could provide cost-effective, high-resolution aerial imagery in this isolated part of southeastern San Bernardino County that could be used to provide a historical record, as well as aiding the difficult task of identifying abandoned solid waste materials, determining their historical significance, and supporting cleanup efforts. This mission successfully demonstrated the UAS's ability to function as a low altitude reconnaissance and monitoring tool. The image data acquired with the sUAS could be used, either in real-time or during post-processing, to provide coordinates for the location of identified materials (Figure 5). Having access to this geographic coordinate information allows the inspectors to save time by easily navigating directly to the required inspection sites.

An unexpected benefit from this high-resolution imagery was its ability to distinguish various vegetation types, including Joshua trees (Figure 6). Image data with this level of resolution can be used with automated extraction techniques to create vegetation information, which would provide resource managers with a reliable method for creating vegetation inventories.

"The Department's field-level staff are driving the investigations of UAS technology."

Other OT&E mission summaries can be found at the USGS NUPO website, http://uas.usgs.gov/.

Figure 5. UAS image of abandoned materials in the Mojave National Preserve (USGS).

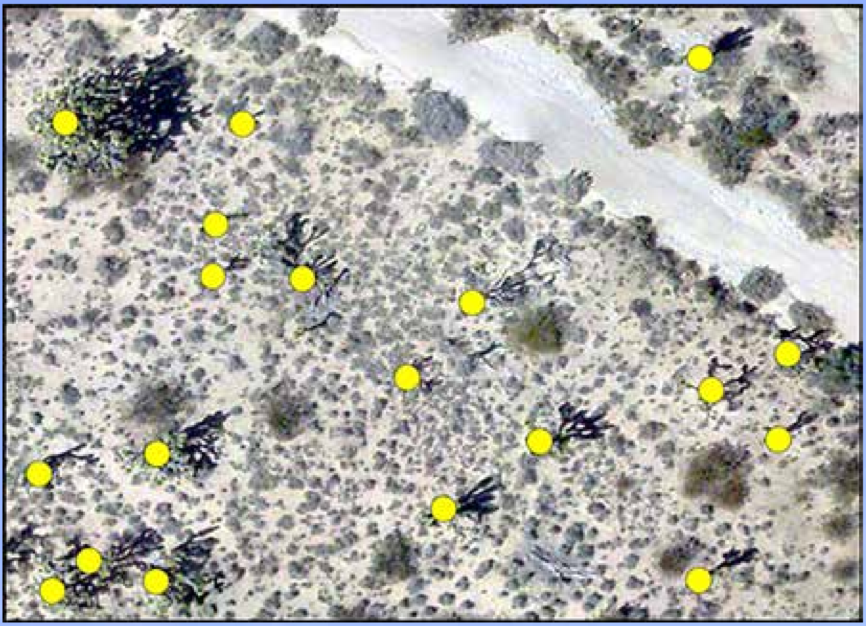


Figure 6. Feature extraction of Joshua trees, indicated by yellow dots, collected for vegetation inventories (USGS).

Conclusions

Not since the invention of the airplane or global positioning system (GPS) has a technology had such a disruptive and transformational impact on the remote sensing community. Tully (2013) has called it the rise of "personal remote sensing" where more and more people will have access to the technology. Others have heralded the UAS ability to let the science questions drive the remote sensing data acquisitions, rather than the data driving the science.

UAS technology has the potential to enable the DOI to be a better steward of the land by:

- Improving natural hazard forecasting and the analysis of the impacts.
- Improving our understanding of climate change to better plan for likely impacts.
- Developing precipitation and evaporation forecasting to better manage water resources.
- Monitoring Arctic ice change and its impacts on ecosystems, coasts, and transportation.
- Increasing safety and effectiveness of wildland fire management.
- Enhancing our search and rescue capabilities.
- Broadening our abilities to monitor environmental or landscape conditions and changes.
- Better understanding and protecting the Nation's ecosystems.

The initial operational testing and evaluations performed by the DOI have proven that UAS technology can be used to support many of the Department's activities. UAS technology provides scientists a way to look longer, closer and more frequently at some of Earth's most remote areas—places that were previously too dangerous or expensive to monitor in detail. The flexibility of operations and relative low cost to purchase and operate sUAS enhances the ability to track long-term landscape and environmental change. The initial testing indicates the operational costs are approximately 10% of traditional manned aircraft. In addition, users can quickly assess landscape-altering events such as wildland fires, floods and volcanoes. UAS technology will allow the DOI to do more with less and in the process enhance the Department's ability to provide unbiased scientific information to help stakeholders make informed decisions. It will also provide a digital baseline record that can be archived and used when monitoring future events or conditions. One possible future scenario has scientists carrying sUAS into the field allowing quick deployment and operation to observe the environment or for emergency response. This scenario could also include a persistent monitoring capability provided by a UAS that can stay airborne over a small geographic area for days or weeks, or possibly longer.

While the DOI focus is on sUAS, the Department recognizes that larger UAS systems will also play a role in meeting its mission. The Department anticipates meeting long-duration or specialized acquisition commitments, such as state or national aerial photography, by collaboration with other agencies or through commercial contracts.

Even though the DOI continues to evaluate UAS and sensor technology to meet the Department's mission, some of its bureaus are already moving towards an operational capability. We fully anticipate that by 2020 UAS will emerge as one of the primary platforms for DOI remote sensing applications.

"Not since the invention of the airplane or global positioning system (GPS) has a technology had such a disruptive and transformational impact on the remote sensing community."

Acknowledgements

The authors would like to acknowledge the USGS National UAS Project Office (Jeff Sloan, Jill Cress, Susan Goplen, Mark Feller, Mark Bauer, Isaac Anderson, Lance Brady), Mark Bathrick and his staff at the DOI Office of Aviation Services, and most importantly the numerous field level scientists and resource managers across the DOI for their support in introducing an innovative, paradigm shifting technology. For more information see http://uas.usgs.gov/.

References

Department of the Interior, 2013. *DOI OPERATIONAL PROCEDURES (OPM) MEMORANDUM NO. 13-11*, *DOI Use of Unmanned Aircraft Systems (UAS)*, Office of Aviation Services, Boise, Idaho, 6 p.

Patterson, M.C.L, A. Mulligan, J. Douglas and J. Robinson, 2005. Volcano

Surveillance by ACR Silver Fox, American Institute of Aeronautics and

Astronautics, URL: http://pdf.aiaa.org/preview/CDReadyMIA05_1246/PV2005_6954.pdf, Arlington, Virginia (last date accessed: 25 June 2014).

Sasse, D. Blake, 2003. Job-related mortality of wildlife workers in the United States, 1937-2000, *Wildlife Society Bulletin*, 31(4):1015-1020.

Tully, Mike, 2013. The Rise of the [Geospatial] Machines Part 3: New Opportunities in the Coming Unmanned Aerial Systems (UAS) Age, Sensors and Systems, URL: http://www.sensorsandsystems.com/article/columns/32612-the-rise-of-the-geospatial-machines-part-3-new-opportunities-in-the-coming-unmanned-aerial-system-uas-age.html, (last date accessed: 25 June 2014).

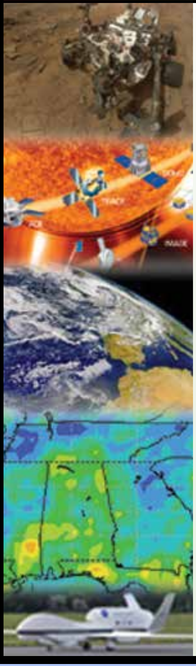
OpusTek International Corporation, 2011, United States Geological Survey Unmanned Aircraft Systems Roadmap 2010-2025, Arlington, VA, OpusTek International Corporation, 187 p. [Prepared under contract to U.S. Geological Survey, solicitation number 10CRQQ0260.]

Authors

Bruce K. Quirk, *U.S. Geological Survey*, Reston, VA, quirk@usgs.gov

Michael E. Hutt, *U.S. Geological Survey*, Denver, CO, mehutt@aol.com

Background image courtesy of http://www.free-pictures-photos.com/



sort of!

USS (Unmanned Santa Syste[m]) Controversy at the North Po[le]

Over the last several years, excitement has been growing at the North Pole among Santa's Elves about creating a Drone Section (aka "Section D"). The creation of this new department would complement the current North Pole Departments, "Section S" (sleigh), "Section R" (reindeer), "Section T" (technology), and the all-important "P-Section" (presents). However, within all the excitement, there is of course, a bit of debate. The North Pole Press Corp was able to secure key interviews with some of the leading elves involved in this major Unmanned Santa Systems controversy.

The Chief Elf (whose identity cannot be disclosed) put it this way: "We have never before been able to give Santa a tool that is so scalable, so easy to maneuver, so flexible to manage, and that fills a gap between what we have right now for delivering toys and what we see as our future needs." On the other hand, many elves say that things are "working just fine, so why try to fix what is not broken?" Rudolph's handler, who is, what is now becoming known as, an "elf traditionalists" said, "Look, don't all deserving kids already get their toys on time?"

When asked exactly how Santa plans to incorporate UAS into North Pole operations, Santa's Chief Elf Technologist refused to say. Instead, she said, "North Pole operations are magic, and we don't disclose the inner workings of how magic is done here at the North Pole. Do you want to spoil Christmas for everyone?" As the interview progressed, she softened up a bit and said, "think about researching where kids live, about planning efficient and flexible routing, think about Santa's sleigh as the mother ship and, well, I've said too much already…". This one comment from the Chief Elf Technologist convinced me that there was more to find out about the use of UAS at the North Pole. There is clearly sincere and direct interest in this technology.

Next, I was able to secure an interview with Santa's head of security and he noted, "We have to be really careful talking about this stuff. The Grinch already stole Christmas once, and we can't have that happen again." Indeed, there are rumors going around the North Pole that the Grinch is experimenting with "drone technology." Some say the Grinch plans to use a fleet of fixed wing drones to swoop down from above and lift presents off Santa's sleigh one by one while in flight. Others say the Grinch is instead building an army of rotary wing drones capable of maneuvering down chimneys to steal presents after Santa delivers them. "On the bright side of things," Santa's head of security stated, "until the Grinch can figure out how to hack Santa's brain, our database of where kids live is safe – it's completely offline in the safety of the man himself, in Santa's head."

The story was really taking-off and achieved an extra dimension when talking to the average elf on Christmas Lane. They say that things are not running as smoothly at the North Pole as they appear. Lily Elf, a veteran of five Christmases, says that Santa "does a great job of keeping things on track" but that each year "we have more and more presents that we have to go back and redeliver, and the reindeer are having near misses and are sometimes sliding off the edge of rooftops." Lily Elf's friend, Fily Elf, said this: "You wouldn't believe the time and energy we spend fixing simple mistakes that just a little bit of technology could have prevented."

Santa's Chief Historian, Hily Elf, has a different opinion. He said, "Technology is not the answer to everything. Some problems are cultural." He cited the example of when Rudolph first came on the scene. His blinking nose technology made a huge impact on North Pole operations. But it wasn't easy, he said: "At first, all the other reindeer wouldn't let him play in any reindeer games." It was Santa who had to show his leadership and force the cultural change by asking, "Rudolph, with your nose so bright, won't you guide my sleigh tonight?" That changed everything.

Santa's Chief Elf Technologist further commented, "it's not just UAS that we're looking at. There is a push to modernize North Pole operations in every possible way – from putting RFID tags on presents to using GPS to navigate around the globe." Aily Elf, who is on Santa's safety team and whose job it is to coordinate with FAA and other aviation authorities put it this way: "The skies, even on Christmas Eve, are a lot more crowded today than they were

MS) EXCITEMENT AND
E

MICHAEL HAUCK, NORTH POLE PRESS CORP

500 years ago. Safety concerns are paramount. The last thing we want to happen is for there to be an air collision and someone gets hurt on, the happiest night of the year, Christmas Eve."

Adding to the safety concerns, there have been near misses. Gily Elf, a geodesist who sometimes gets to ride with Santa, agrees, "Everybody thinks inertial navigation works great, but when we can't see the stars or other fixed reference points at least once in a while, things get hairy. I remember one time in particular, we almost slammed right into the side of the Abominable Snowman's mountain!" Santa's Chief Safety Elf, however, said, "Everybody calm down now. There has NEVER been an accident in the history of North Pole operations." Nonetheless, Grandpa disagrees, claiming that Grandma got run over by a reindeer one Christmas Eve.

Even Rudolph's handler admits, "It's true, Rudolph's nose doesn't seem as bright as it used to be. Not sure if it's more about 21st Century smog that's hard to see through, or if Rudolph is getting on in years." Either way, the sleigh outfitters have found it necessary to equip Santa's sleigh with LED beacons. Although no elves would allow themselves to be quoted, many admit off the record that the LEDs shine brighter than Rudolph. Upon hearing that, Mrs. Claus said, "It's a sad state of affairs at the North Pole when elves think blinking electric lights are an OK way to do Christmas."

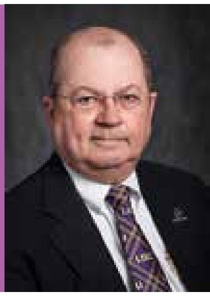
Santa was not available for comment. He is in rehab. Apparently, Mrs. Claus gave Santa a Fitbit ® wristband for Christmas last year. Santa became addicted to it and has been obsessively tracking his exercise and calories burned. He has lost over 100 pounds since last Christmas and is now on a crash diet to get his weight back up before the big day. While in rehab, to help Santa Claus keep up his good cheer, the elves gave him a set of remote-controlled reindeer to play with. The Chief Elf said, "They aren't real UAS because they are just a hobby for Santa right now. Still, Santa thinks they have a lot of potential for revolutionizing his business, and he is welcoming the new technology. But for right now, he certainly enjoys doing loopity-loops with them."

The official use and adoption of Unmanned Santa Systems controversy continues. Perhaps soon, new technology and advanced systems will be utilized in a way only the magic of the North Pole could imagine. For now, all the children around the world can rest easy knowing the team at the North Pole is working very hard on another successful Christmas.

FIRST ASPRS UAS MAPPING 2014 SYMPOSIUM

The first ASPRS UAS Mapping Symposium was held in Reno, Nevada on October 21-22, 2014, organized by the ASPRS Northern California Region.

It featured over 500 attendees and 50 exhbitors assembled for talks, demonstrations, and networking. Highlights included a special conference video "Change is in the Air", an inspirational talk by innovator/entrepreneur Dr. Brandon Basso of 3D Robotics who spoke on the future of mapping, and a special welcome by the Mayor of Reno. Attendees also traveled to the "turf farm" to see the calibration/validation range laid out by conference organizers for hobby fliers that included radiometric targets and surveyed locations. ASPRS president Dr. Stewart Walker likened the energy in the room to the days when satellites and remote sensing brought a whole new technical dimension to the Society.



Grids & Datums

Republic of TAJIKISTAN

BY Clifford J. Mugnier, CP, CMS

"The Tajiks, whose language is nearly identical with Persian, were part of the ancient Persian Empire that was ruled by Darius I and later conquered by Alexander the Great (333 B.C.). In the 7th and 8th centuries, Arabs conquered the region and brought Islam. The Tajiks were successively ruled by Uzbeks and then Afghans until claimed by Russia in the 1860s. In 1924, Tajikistan was consolidated into a newly formed Tajik Autonomous Soviet Socialist Republic, which was administratively part of the Uzbek SSR until the Tajik ASSR gained full-fledged republic status in 1929.

"Tajikistan declared its sovereignty in Aug. 1990. In 1991, the republic's Communist leadership supported the attempted coup against Soviet president Mikhail Gorbachev. Tajikistan joined with ten other former Soviet republics in the Commonwealth of Independent States on Dec. 21, 1991. A parliamentary republic was proclaimed and presidential rule abolished in Nov. 1992. After independence, Tajikistan experienced sporadic conflict as the Communist- dominated government struggled to combat an insurgency by Islamic and democratic opposition forces. Despite continued international efforts to end the civil war, periodic fighting continued. About 60,000 people lost their lives in Tajikistan's civil wars" *(Infoplease, 2014).*

Slightly smaller than Wisconsin, Tajikistan is bordered by Afghanistan (1,206 km) (*PE&RS*, January 2004), China (414 km) (*PE&RS*, May 2000), Kyrgyzstan (870 km) (*PE&RS*, September 2014), and Uzbekistan (1,161 km) (*PE&RS*, December 1998). The terrain consists of the Pamir and Alay Mountains that dominate the landscape; western Fergana Valley in the south; (Sirdaryo) at 300 m; the highest point is Qullai Ismoili Somoni at 7,495 m *(World Factbook,2014).*

"In the early 19th century the Russian penetration began into the area between the Caspian Sea and Iran, Afghanistan, and China. In 1839, the Russian Army moved into the area of Turkestan which was for centuries an object of struggle between Turko-Iranian and Chinese influences and completed its occupation in 1857. In 1867, the Military Topographic Department of Turkestan was formed and was headed by a major or brigadier general. The Astronomic and Physical Observatory of Tashkent was founded officially in 1878. The city of Tashkent, now the capital of Uzbekistan became the capital of Turkestan, and by 1888 the region of Transcaspia, now in southwest Kazakhstan was incorporated as a new province. The new government of Turkestan incorporated Khokanda, Tajikistan in 1875, and the Fergana Valley, Tajikistan in 1876. Triangulations from 1896 to 1929 were based on base lines measured with Jäderin apparatus (invar steel and brass wires) at Kyzyl Rabat in southern Tajikistan and oriented primarily on Osh Datum. Osh, II (NW) Base Point determined in 1909 by Davidov is where: Φo = 40º 37' 16.67" N ± 0.10", Λo = 42º 36' 32.625" E of Pulkovo ± 0.092". Determined by a short passage of chronometer from Astro point Osh, Old Church with Λo = 42º 28' 32.26" E of Pulkovo ± 0.45" determined in 1884 by telegraph, αo = 152º 54' 01.86" ± 1.26" to I (SE) Base Point, and the ellipsoid of reference is the Bessel 1842 where: a = 6,377,397.155 meters, and $1/f$ = 299.1528128. The Kyzyl Rabat base line was at SW base point – NE base point measured in 1912 and was 8,395.683 m ± 0.00241 m, where: Φo = 37º 26' 40.28" N ± 0.42" N, Λo not determined, and αo = 75º 45' 22.72" ± 0.60" to NE Base Point *(Zapiski VTU, Vol. 69 Pt. 2 pl 235; Geodezist Vol. 11-12, p.30).* Starting from the Kyzyl Rabat base line, there were 8 triangles triangulation of India.

"The main chain with the side Beik (Sarblok)-Ak-turuk-tau (Kuhtek) is on the Beik Pass tied to the British Triangulation of India. The British chain of connection is composed of 7 geodetic quadrilaterals with diagonals, 2 central quadrilateral systems and 11 simple triangles – together 47 triangles withch connect 33 stations. It is computed on the ellipsoid of Everest 1830 with the datum of Kalianpur. The Indian Datum of 1916 origin at Kalianpur Hill Station is: Φo = 24º 07' 11.26" North, Λo = 77º 39' 17.57" East of Greenwich. The defining azimuth at the point of origin to station Surantal is: αo = 190º 27' 05.10". The ellipsoid of reference is the Everest 1830, where a = 6,377,276.345 meters, and $^{1}/f$ = 300.8017.

"In order to make the comparison, Russian coordinates of Tashkent Datum and Bessel ellipsoid for the tie points: Beik (Sarblok) φ = 37º 18' 48.28" N, λ = 44º 44' 56.81" E, α = 248º 12' 53.7" to Ak-turuk-tau (Kuhtek), and Ak-turuk-tau (Kuhtek) φ = 37º 17' 22.29" N, λ = 44º 40' 27.80" E, α = 68º 10' 10.7" to Beik were converted by Helmert's formulae *(Jordan-Eggert Handbuck der Vermessungskunde Vol. iii/1923 pg. 737)* to the ellipsoid of Everest *(Triangulation in Turkestan and its Connection with India, Andrew M. Glusic, Army Map Service Technical Report No. 21, February 1957, 100 pages). (Note that the resultant disparities of Russian Tashkent datum minus British Kalianpur datum for Beik (Sarblok) were: Δφ = –10.73", Δλ = –5.22", Δα = –16.9", and for Ak-tutuk-tau (Kuhtek) were: Δφ = –10.77", Δλ = –5.29", Δα = –16.8" – Ed.).*

Significant progress in geodetic surveying activities and cadastral mapping has been accomplished in the 21st century including high resolution satellite imagery referenced to the ITRF2005 on the UTM Grid System *(Transfer of Technology for Cadastral Mapping in XXXIX-B6, 2012 XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia.).*

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or the Louisiana State University Center for GeoInformatics (C[4]G).

INDUSTRYNEWS

ANNOUNCEMENT

GeoCue® Group Inc. (via its wholly owned subsidiary, QCoherent Software LLC) is pleased to announce the release of LP360 2014.1. This release includes many new features, performance improvements and stability enhancements. A number of features specifically aimed at processing data from sensors flown on small Unmanned Aerial Systems (sUAS) have been added. A new packaging of LP360 called "LP360 for sUAS" has been added to the product line (currently analogous to LP360, Standard Edition).

Everyone who has LP360 on current maintenance will be able to update to the new release by using the "LP360 – Check for updates" feature in LP360. . Additional information can be found at www.LP360.com or by inquiry via email (info@LP360.com).

BEHIND THE SCENES

A technical look inside the present and future of geospatial and imaging technologies

by Jim Peters, CP*

What's Hot about Thermal Imaging?

If you Google the phrase "thermal imaging" in the fall of 2014, you will find links to the release of cell phone compatible thermal cameras to assist with ground based energy audits of your home or office. For most of us, we are more familiar with viewing color imagery in the visible spectrum between 0.4 µm and 0.7 µm (to the naked eye that would be the range of colors from violet to red). When you think of the term thermal, thermal can cover the electromagnetic spectrum from near infrared to long wave infrared. Near infrared is collected in the [0.7 µm to 2.5 µm]. One application for using the NIR range is to detect the amount of chlorophyll in vegetation for reliable plant condition analysis. The long-wave infrared (LWIR) range of the electromagnetic spectrum is detectable within a wavelength of 8 µm to 15 µm, which we feel as warmth, but don't see. To put this into perspective, humans at normal body temperatures radiate near 10 µm. This is why thermal imaging is a critical tool in search and rescue missions both in use by the military and civilian entities.

For an aerial thermal camera to capture a digital LWIR image, the camera will be detecting energy intensity that is radiated from objects visible to the sensor in the 8 µm to 15 µm range. The amount of thermal radiation emitted depends on the emissivity values of the structure's surface (i.e., a painted metal roof versus a nearby water pond). Emissivity ranges in values of 0 to 1 as it represents the ratio of existence from a real object to the existence of a perfect black-body at the same temperature. A black-body is an ideal material that allows all incident radiation to pass into it with no energy reflected from it. In nature there are no materials with an emissivity of 1 but within the geographic environment there are a few features that are close to 1 and water is one of them.

Water features like lakes and ponds can be used as relative black-body features for control objects in a thermal imagery project. Thermal IR imagery is typically flown at night when solar loading is at a minimum. Water with an emissivity of 0.97 will be absorbing thermal energy during the day. Water also has a small diurnal temperature variance as water warms slowly after sunrise and cools slowly after sunset reaching a minimum near dawn. Due to the nature of natural features near the water (soil and vegetation as shown in Figure 1a), the water will appear warmer than the surrounding land (see Figure 1b). The varying shades of orange (in Figure 1b) are an indicator of differing amounts of sediment in the water body.

Thermal imagery proves to be a great method for stream location when vegetation covers areas of hydrography features. Figure 2a shows tree canopies over parts of the stream channel. Thermal imagery in figure 2b can be used to aid in the location of the stream since water will be a warmer feature in the imagery as compared to the surrounding geographic features.

Figure 1a. A natural color image showing water/vegetation area at NASA Langley Research Center. **

Figure 2a. Several locations of the linear hydrography feature are hidden by tree canopies. **

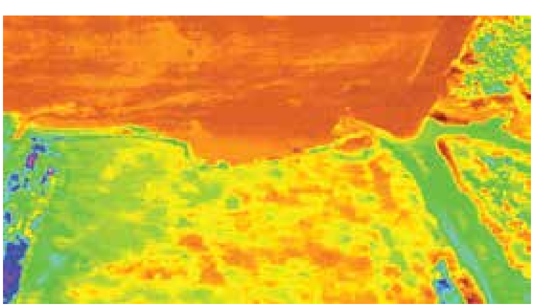


Figure 1b. During a night-time thermal imagery capture, water can be used as a black-body source to validate temperatures of features in the imagery. **

Figure 2b. Delineation of streams can be derived from thermal imagery. **

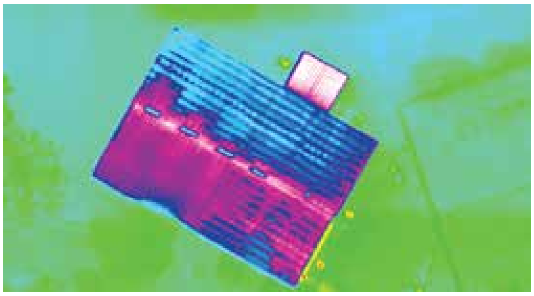


Figure 3a. Long-wave thermal imagery showing warmer (shades of blue) on the north facing slope of the roof compared to the cooler (violet) south facing slope. **

Figure 3b. The natural color image showing a metal roof building (as seen in Figure 3a) at NASA Langley Research Center. **

A developing trend in the use of aerial thermal imagery (long wave IR) is for determining heat loss from building structures. In using thermal imagery, infrastructure managers can determine roof locations where more insulation is needed to reduce heating costs. Figure 3a shows varying warmer heat signatures on the north side of the roof as compared to the cooler (violet) temperatures on the southern side of the structure. For reference, figure 3b shows the natural color image of the same structure.

With aerial thermal imagery providing people with insight to the location of possible heat loss of their home or business, my google search found a "cool" apple/android compatible cell phone thermal camera and app to show thermal signatures. The link was for the IR-Blue at the https://www.kickstarter.com/projects/andyrawson/ir-blue-thermal-imaging-smartphone-accessory. The IR-Blue was first developed and made available through the Kickstarter crowd funding organization. This Kickstarter web site is the best link to review the device and has additional links to the RHWorkshop.com for current purchase options (just under $200). If you are a gadget geek or just interested in determining heat loss for your home, the IR-Blue looks to be an interesting device to determine issues prior to hiring a professional energy auditor.

So, what's so hot about thermal imagery? Put simply, it highlights heat anomalies, both hot and cold. That is why alien predators in the movies use thermal sensors to detect the human game they are hunting. Fortunately for us humans, mud is a great camouflage. It both masks the heat from our bodies, and matches the thermal emissivity of the area around us – assuming, that is, that we are in a jungle. Mud probably won't save us from being eaten in the desert, but thermal imagery would certainly help us find water.

** Imagery provided by courtesy of NASA Langley Research Center's GIS Team.

I would love to hear ideas for future columns. What are you curious about?

Write me at: jim@icaros.us.

*Jim Peters is a Client Development Manager at Icaros, Inc. For ASPRS, he currently serves as the Chair for the Electronic Communications Committee.

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or Icaros, Inc.

With several decades of experience across a broad spectrum of remote sensing, I am excited by the broad range of advancement now underway in this field. Therefore, I was eager to read *Advances in Mapping from Remote Sensor Imagery,* edited by Xiaojun Yang of Florida State University and Jonathan Li of the University of Waterloo, Canada.

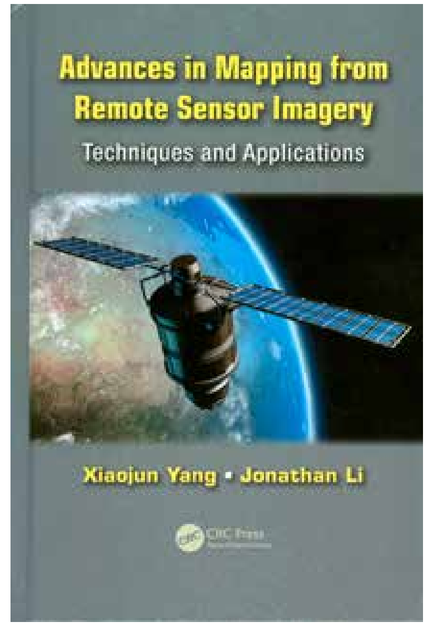
The physical characteristics of a book are important and the first things that come to the reader's attention. In this hardbound book the paper is a pleasingly bright white and the font is easily read, even for the old eyes of this reviewer. The feel of the paper is coarser than I desire but is typical of many new books. Color plates are collected together and are printed on noticeably darker and yellowish paper, but the colors are vibrant and easily discriminated. And only Figure 16.8 has the too common defect of too much detail for too large an area.

This text is a compilation of 16 chapters. Each chapter is written by different authors and starts with a numbered outline with pagination and an introductory "abstract". I like the outline, and some of the authors took advantage of this format to develop their texts in a nicely structured way. The "abstracts" are less useful, especially as the editors did not always prevent the abstract from being immediately repeated in the body of the chapter, as is the case in chapter 1.

The preface asserts the book is to be considered in three major parts. This reader could not detect any structure to the choice or order of the chapters. The emphasis is clearly on recent developments in land or near shore mapping using data from aircraft or orbit, not strictly imagery. Thus LiDAR receives considerable and useful discussion in chapters 2 and 7, with sections in other chapters as well. The use of interferometric synthetic aperture radar (SAR) for measuring elevation and elevation changes is very well covered in chapters 4, 5 and 14. Chapters 5 and 14 include some of the relevant basic equations, with adequate context to appreciate how they both constrain and enable the measurements. Chapter 15 covers detection of oil spills in the marine environment by SAR.

To a large extent the book could be considered to have two types of chapters, those that are general discussions of a topic, and those that utilize a limited number of data sets, algorithms for a limited application. In the former this reviewer places chapters:

- 1 Modern photogrammetric mapping
- 2 Airborne LiDAR
- 4 Global digital elevation model development from satellite remotes-sensing data
- 5 Digital elevation model generation from satellite interferometric SAR
- 6 Shore line mapping
- 10 Estimating and mapping forest least area index using satellite imagery
- 16 Remote-sensing techniques for natural disaster impact assessment



Advances in Mapping from Remote Sensor Imagery: Techniques and Applications

Xiaojun Yang and Jonathan Li.

CRC Press 2012. 427 pp. 18 color plates. Hardcover. $150.00 (list). ISBN: 978-1-4398-7458-5. eBook ISBN: 978-1-4398-7459-2

Reviewed by: Doug Rickman, Applied Science Team Lead, Earth Science Office, Marshall Space Flight Center, National Aeronautics and Space Administration

In general these chapters provide good discussions of recent advancements in their respective topics. Chapter 10 is especially good. It provides a context for understanding the recent advances by presenting an overview of the relevant problems and approaches for dealing with them.

The remaining chapters, listed below, while useful to some readers deliver less than the book and chapter titles suggest. These would be better labeled as case studies. The authors of chapters 8, 9, 12 and 13 explicitly acknowledged the limitation on significance imposed by their restricted choices. Regrettably, the other authors do not do so, leaving the reader without guidance on applicability. If anyone is interested in the book specifically for one or two of these chapters, I would instead recommend using the author's journal publications as

continued on page 1105

WHAT IS ASPRS?

Founded in 1934, the American Society for Photogrammetry and Remote Sensing (ASPRS) is a scientific association serving more than 7,000 professionals worldwide. Our mission is to promote the ethical application of active and passive sensors, the disciplines of photogrammetry, remote sensing, geographic information systems, and other supporting geospatial technologies; to advance the understanding of the geospatial and related sciences; to expand public awareness of the profession; and to promote a balanced representation of the interests of government, academia, and private enterprise. We are The Imaging and Geospatial Information Society.

ASPRS MEMBERSHIP

ASPRS would like to welcome the following new members!

At Large
Dinebari Akpee
Yuye Li
Zongyao Sha
Luis Fernando Suarez

Columbia River
Michael Dennis

Eastern Great Lakes
Zach Champion
Steven Ostrowski

Heartland
Richard Wells

Inter-Mountain
Donna Delparte

Mid-South
Mary Grace Chambers
Michael Daniel Simpson

Northern California
Nicholas Barbella
Mihail Pivtoraiko
Tiebiao Zhao
Bryce Tye

Potomac
Suzanne Hollands
Jon Scramlin, II
Mark Simpson

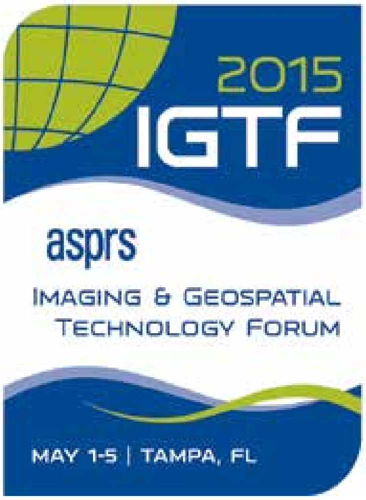
Southwest
Robert E. Davis

Western Great Lakes
Jonathan Guentzel
Evan Applegate

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

Your path to success in the geospatial community

Thank You! Jonathan Li | Yang Quan Chen | Dr. Michael Krimmer
FOR SPONSORING SOME OF OUR NEW MEMBERS!



INTRODUCING THE RE-DESIGNED, RE-IMAGINED AND RE-THOUGHT ASPRS ANNUAL CONFERENCE…..

THE IMAGING & GEOSPATIAL TECHNOLOGY FORUM - IGTF 2015 AND CO-LOCATED JACIE WORKSHOP

MAY 6 – 8, 2015 * TAMPA, FLORIDA

The ASPRS Annual Conferences have been RE-designed, RE-imagined and RE-thought with YOU in mind!

The NEW Imaging and Geospatial Technology Forum (IGTF) will be held at the Tampa Marriott Waterside Hotel, Tampa, Florida, May 6 through May 8, 2015.

The Imaging and Geospatial Technology Forum was created to encompass the broadest terms for our industry, "Imaging" and "Geospatial", while incorporating the idea of "Technology" as this concept is the center and reason we all come together. We decided to use the word "Forum" instead of conference because Forum means to assemble or a meeting place for the discussion of questions, promoting open discussion and sharing. And the sharing of ideas and open discussion is the core value for each event. All these elements together formed the new look and feel for ASPRS Annual Conferences - The Imaging and Geospatial Technology Forum (IGTF).

The all new IGTF 2015 will bring innovative presentations, dynamic keynote speakers, an exciting Technology Floor, a new conference layout and MUCH, much more!

Be sure to watch the forum website as this new design takes shape.

Book Review

continued from page 1103

a potential savings. Still, having the topics assembled into a book has a definite utility.

- 3 Advanced algorithms for land use and cover classification
- 7 Seeing residential buildings from remotely sensed imagery
- 8 Assessment of urbanization patterns and trends in the Gulf of Mexico region
- 9 Fractional vegetation cover mapping from the HJ-I small satellite hyperspectral data
- 11 Effects of the spatial pattern of vegetation cover on urban warming in a desert city
- 12 Remote sensing of algal blooms in inland waters
- 13 Advanced geospatial techniques for mapping and monitoring invasive species
- 14 Surface deformation mapping with persistent scatterer radar interferometry
- 15 Mapping marine oil spills from space

Given the title of the book I expected detailed discussions of algorithms. Chapter 2 is quite good in this respect and several other chapters, such as 7, 9, 10, 11, 12, are substantially focused on algorithms and are useful. However, land use and land cover classification, a core function for mapping with remote sensing, has one chapter dedicated to this topic: "Advanced algorithms for land use and cover classification" (chapter3) was a disappointment in its brevity and application. The chapter gives a combined page and a half to brief discussions of maximum likelihood and neural networks; the remainder discusses Support Vector Machines (SVM) and Random Forest algorithms. The authors of this chapter attempt to draw general conclusions based on just two data sets, one 307x330 pixels, the other 512x512.

In summary, I find that the book definitely has a place on my shelf. Based on the range of topics covered, this book will benefit both students and professionals as an introductory remote sensing source.

Geospatial Applications of Big Data Analytics

The volume of data created by an ever increasing number of remote sensing platforms and the capability of modern platforms to collect data at ever increasing spatial, spectral, and radiometric resolutions currently exceeds petabytes of data per year and is only expected to increase. The variety of geospatial data available for adding valuable information to traditional remote sensing imagery, including social media and sensors as part of the so-called internet of things (IoT) promises to add information value if it can be effectively integrated. The velocity of all this information is critical, as the information value of all this information degrades if it can not be processed in a timely manner not only for military, intelligence, and other traditional consumers of geospatial data but also for the new breed of geospatial data consumers in areas such as business analysis and logistics. Recent developments in information technology commonly referred to as 'Big Data' along with the related fields of data science and analytics will need to be brought to bear in order to process, analyze and realize the value of the overwhelming amount of geospatial data the remote sensing community is capable of generating.

This special issue of *Photogrammetric Engineering and Remote Sensing (PE&RS)* will focus on the application of advances in Big Data analytic techniques to geospatial applications in the commercial, government and academic remote sensing communities. Papers covering topics including, but not limited to, the following are invited for consideration:

- Technologic advances in hardware, storage, data management, networking and computing models such as virtualization and cloud computing for geospatial applications.
- Creative uses of Big Data innovations such as MapReduce, Hadoop, Big Table and NoSQL in geospatial processing.
- Usage of human-created, machine-created, structured and unstructured data in geospatial analytics including the integration of geospatial information from non-imaging sensors and the Internet of Things (IoT) with more traditional forms of geospatial information.
- Discovery of patterns in large volumes of geospatial data through analytic techniques such as data mining and predictive analytics in applications such as human geography.
- Development of new processing algorithms to handle large volumes of data, for instance through application of functional programming languages such as Lisp, R, and Clojure to geospatial applications.
- Creation of new visualization products that increase the understanding of large and diverse forms of information.

Authors must prepare manuscripts according to the *PE&RS* Instructions to Authors, published in each issue of *PE&RS* and also available on the ASPRS Website at www.asprs.org/pers/AuthorInstructions . All submissions will be peer-reviewed in accordance with *PE&RS* policy. Because of page limits, not all submissions recommended for acceptance by the review panel may be included in the Special Issue. Under this circumstance, the guest editors will select the most relevant papers for inclusion in the special issue. Papers that are reviewed favorably, but will not fit within the Special Issue, can be revised and submitted for review as a new paper to the *PE&RS* Editor-in-Chief for possible publication in a future regular issue of *PE&RS*.

Deadline for Submission of Manuscripts: 05/01/15

Tentative Publication Date: 04/01/16

Guest Editors:

Harold J Cline, Tomra Sorting Solutions, Mining

David Alvarez, Woolpert

Please e-mail your manuscript directly to:

Harold Cline
Email: harold.cline@tomra.com
Phone: (720) 361-9033

Important Dates:

Manuscripts Due: 05/01/15

Decision to Authors: 09/01/15

Final Papers Due: 10/01/15

Publication: 04/01/16

GPU Processing for UAS-Based LFM-CW Stripmap SAR

Craig Stringham and David G. Long

Abstract

Unmanned air systems (UAS) provide an excellent platform for synthetic aperture radar (SAR), enabling surveillance and research over areas too difficult, dangerous, or costly to reach using manned aircraft. However, the nimble nature of the small UAS makes them more susceptible to external forces, thus requiring significant motion compensation in order for SAR images to focus properly. SAR backprojection has been found to improve the focusing of low-altitude stripmap SAR images compared to frequency domain algorithms. In this paper we describe the development and implementation of SAR backprojection appropriate for UAS based stripmap SAR that utilizes the unique architecture of a GPU in order to produce high-quality imagery in real-time.

Introduction

Unmanned air systems (UAS) carrying synthetic aperture radar (SAR) can obtain high-quality high-resolution information over areas too difficult, dangerous, or costly to reach using manned aircraft. SAR systems are active radars that transmit and receive microwave signals. The received signals are used to create images of the surface and are able to operate regardless of illumination or weather conditions. The nimble nature of a small UAS makes it much more mobile but also more susceptible to external forces, thus requiring significant motion compensation in order for SAR images to focus properly. Low-altitude operation further complicates motion compensation of stripmap SAR images, due to the large range of incidence angles and increased range cell migration. SAR backprojection inherently handles arbitrary aircraft motion and low-altitude geometry and can form images directly along known topography making it a particularly effective algorithm for UAS-based SAR. However, backprojection is much more computationally demanding than frequency domain algorithms (Melvin and Scheer, 2012). Fortunately, backprojection processing is easily parallelized and computed efficiently on graphics processing units (GPU). Several studies have been conducted on implementing backprojection on GPUs, most notably Fasih and Hartley (2010), Benson *et al.*, (2012), Capozzoli *et al.* (2013), and Nguyen *et al.* (2004), but these papers focus on the simplest form of spotlight mode SAR backprojection and are not directly applicable to stripmap SAR. In this paper we present the development and implementation of a highly efficient GPU-based SAR backprojection processor for stripmap imaging. In particular, we develop a stripmap processor for linear frequency-modulated continuous-wave (LFM-CW) SAR systems operated on a UAS.

This paper is organized as follows. We begin with a background discussing the LFM-CW signal, stripmap SAR, and a brief introduction to the NVIDIA GPU architecture and Compute Unified Device Architecture (CUDA). Then, we develop a SAR backprojection method that accounts for motion during the pulse and the moving antenna pattern, which is suitable for UAS based stripmap SAR. This is followed by a discussion of the implementation of the SAR processor on a GPU. Finally, we use SAR data from CASIE 2009 (Long *et al.*, 2010) to analyze the performance of the implementation and present the resulting imagery.

Brigham Young University, 459 Clyde Building, Provo UT 84602 (stringham@ieee.org).

Background

LFM-CW Signal

Modern SAR systems can be very small, low-power, and lightweight such that they can be used on a small UAS. This reduction in size has greatly been made possible by technology advancements and the use of LFM-CW technology. LFM-CW radars maximize the signal to noise ratio (SNR) achievable for a given peak transmit power by continuously transmitting, maximizing the energy of the received signal. To achieve high-resolution, the transmit signal is modulated over a wide range of frequencies.

The transmit signal of an LFM-CW radar can be described as the complex exponential:

$$s_t(\eta,t) = \exp\left\{-j\left(2\pi f_0 t + \pi k_r t^2 + \varphi\right)\right\} \tag{1}$$

where f_0 is the carrier frequency, k_r is the chirp rate, φ is the initial phase of the system, and η and τ are respectively "slow-time" and "fast-time" which are typical SAR notation. Slow-time changes discretely with each pulse while fast-time ranges over the length of the pulse, T_p. The received signal from a single scatterer with position, $\vec{x}$, can be described as an attenuated, time-delayed copy of the transmit signal. The received signal can be written as:

$$\begin{aligned} r_{\vec{x}}(\eta,t) &= A_{\vec{x}}(\eta,t)\sigma_{\vec{x}} s_t\left(t-\tau_{\vec{x}}(\eta,t)\right) \\ &= A_{\vec{x}}(\eta,t)\sigma_{\vec{x}}\exp\left\{-j\left(2\pi f_0(t-\tau_{\vec{x}}(\eta,t)) + \pi k_r (t-\tau_{\vec{x}}(\eta,t))^2 + \varphi\right)\right\} \end{aligned} \tag{2}$$

where $A_{\vec{x}}$ is an amplitude function due to the antenna pattern, incidence angle, the distance to the scatterer, and the backscatter from the target is σ_x, and $\tau_{\vec{x}}(\eta,t)$ is the round-trip propagation time of the radar signal, which consists of the time for the pulse to travel from the transmit antenna to the position $\vec{x}$ plus the time for the backscatter to radiate back to the receive anten-

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1107–1115.
0099-1112/14/8012–1107

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

CALENDAR

FEBRUARY 2015

23-25, International LiDAR Mapping Forum (ILMF), Denver, Colorado. For more information, visit lidarmap.org/international.

MAY 2015

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

27-28, Geo Business 2015, London, UK. For more information, visit www.GeoBusinessShow.com.

JUNE 2015

16–25, 15th International Multidisciplinary Scientific GeoConference & EXPO SGEM2015, Flamingo Grand Congress Center, Albena Resort & SPA, Bulgaria. For more information, visit http://www.sgem.org

AUGUST 2015

23-28, On the Map: American Cartography in 2015, Rio de Janeiro, Brazil. For more information, visit www.icc2015.org/

9–13, Optical Engineering + Applications 2015 - Part of SPIE Optics + Photonics, San Diego, California. For more information, visit http://spie.org/optical-engineering

NOVEMBER 2015

9-13, "COSPAR 2015"—2nd Symposium of the Committee on Space Research (COSPAR): Water and Life in the Universe, Foz do Iguacu, Brazil. For more information, visit, http://cosparbrazil2015.org/.

JULY 2016

30–August 7, "COSPAR 2016"—41st Scientific Assembly of the Committee on Space Research (COSPAR), Istanbul, Turkey. For more information, visit http://www.cospar-assembly.org.

FORTHCOMING ARTICLES

Yichun Xie, *Anbing Zhang*, and *William Welsh*, Mapping Wetlands and *Phragmites* Using Publically Available Remotely Sensed Images.

Yonghua Jiang, *Guo Zhang*, *Deren Li*, *Xinming Tang*, *Wenchao Huang*, and *Litao Li*, Correction of Distortions in YG-12 High Resolution Panchromatic Images.

Michael Campbell, *Russell G. Congalton*, *Joel Hartter*, and *Mark Ducey*, Optimal Land Cover Mapping and Change Analysis in Northeastern Oregon Using Landsat Imagery.

Omar E. Mora, *Jung-kuan Liu*, *M. Gabriela Lenzano*, *Charles K. Toth*, and *Dorota A. Grejner-Brzezinska*, Small Landslide Susceptibility and Hazard Assessment Based on Airborne Lidar Data.

Xiaodong Li, *Yun Du*, and *Feng Ling*, Sub-Pixel Land Cover Map Updating by Integrating Change Detection and Sub-Pixel Mapping.

Han Hu, *Qing Zhu*, *Zhiqiang Du*, *Yeting Zhang*, and *Yulin Ding*, Reliable Spatial Relationship Constrained Feature Point Matching of Oblique Aerial Images.

Gang Hing, *Shusen Wang*, *Junhua Li*, and *Jingfeng Huang*, Fully Polarimetric Synthetic Aperture Radar (SAR) Processing for Crop Type Identification.

Jeffery A. Thompson, *David J. Paull*, and *Brian G. Lees*, An Improved Liberal Cloud-Mask for Addressing snow/Cloud Confusion with MODIS.

Rajagopalan Rengarajan, *Aparajithan Sampath*, *James Storey*, and *Michael Choate*, Validation of Geometric Accuracy of Global Land Survey (GLS) 2000 Data.

Chris W. Strother, *Marguerite Madden*, *Thomas R. Jordan*, and *Andrea Presotto*, Lidar Detection of the Ten Tallest Trees in the Tennessee Portion of the Great Smoky Mountains National Park.

Zhuoting Wu, *Barry Middleton*, *Robert Hetzler*, *John Vogel*, and *Dennis Dye*, Vegetation Burn Severity Using Landsat-8 and WorldView-2.

Muhammad Abdullah Sohl, *Patric Schlager*, *Klaus Schmieder*, and *H.M. Rafique*, Bioenergy Crop Identification at Field Scale Using VHR Airborne CIR Imagery.

Ran Meng and *Philip E. Dennison*, Spectroscopic Analysis of Green, Desiccated, and Dead Tamarisk Canopies.

Mehdi Mazaheri and *Ayman Habib*, Quaternion-Based Solutions for the Single Photo Resection Problem.

Feasibility Study for Pose Estimation of Small UAS in Known 3D Environment Using Geometric Hashing

Julien Li-Chee-Ming and Costas Armenakis

Abstract

A novel self-localization method for small Unmanned Aerial Systems (UAS) is presented. The algorithm automatically establishes correspondence between the First-Person View (FPV) video streamed from a UAS flying in an urban environment and its 3D building model. The resulting camera pose provides a precise navigation solution in the densely structured environment. Initially, Vertical Line Features are extracted from the FPV video frames, as the forward and downward-looking camera is kept stabilized through a gimbal camera mount. Geometric hashing is then used to match the extracted image features with a database of Vertical Line Features extracted from synthetic images of the 3D building models. The exterior orientation parameters of the FPV video frames for localizing the UAS frames are determined by photogrammetric bundle adjustment. The results demonstrate that sub-meter accuracies in the UAS's X, Y, Z positional coordinates are achievable from flying 40 m above ground.

Introduction

First-Person View (FPV) unmanned aerial systems (UAS) are equipped with a small forward-looking video camera and a transmitter to downlink the video signal wirelessly in real-time to a ground station monitor or to virtual reality goggles. FPV gives the operator of a radio-controlled UAS a perspective view from its "cockpit." This allows the aircraft to be flown more intuitively than by visual line-of-sight and beyond the pilot's visual range, i.e., where the aircraft's separation from the pilot is limited only by the range of the remote control and video transmitter. FPV systems are commonly used solely as a visual aid in remotely piloting the aircraft. The obtained quantitative information on position and angular orientation of the aerial platform supports the UAS operator in navigation and path planning. The need for precise navigation is increased in urban missions, where the possibility of crashing is high, as UASs fly at low altitudes among buildings, avoid obstacles, and perform sharp maneuvers. This is especially useful in GPS-denied environments, or in dense-signal multipath environments such as in urban canyons. As such, this work does not require an *a priori* position and attitude estimate of the UAS, perhaps provided by an autopilot.

This work contributes to the localization process of UAS video frames because an FPV video sequence typically consists of thousands of image frames. We propose an approach to obtain the FPV video camera's position and orientation (pose) as it travels through a known 3D environment by matching video image features with features from the 3D model of the environment.

Quickly estimating the UAS's position and orientation is crucial, as the UAS travels rapidly. This ultimately requires an efficient search of the 3D model database. Geometric hashing (Wolfson and Rigoutsos, 1997) has been widely used to determine the feature correspondence between video frames and the 3D model of the environment in on-line applications. Geometric hashing is well-suited for this application as the extracted image features are not compared with every feature in the database; instead, the search space is strategically reduced such that only relevant information is accessed. Geometric hashing is a simple, efficient, and robust feature pattern matching method between two datasets.

The developed self-localization process requires a metric 3D map of the environment. The main steps of the proposed approach are:

1. Generate a database of model Vertical Line Features from synthetic images of the 3D map.
2. Extract Vertical Line Features from the video frames.
3. Use geometric hashing to match the extracted image features with their corresponding model features in the database.
4. Determine the camera position and orientation parameters, as a function of the matched feature locations in the map using a photogrammetric bundle adjustment solution.

Notably, the proposed approach estimates the required initial approximations for the exterior orientation parameters, thus the onboard sensors (i.e., the GPS, IMU, and magnetometer) were not used in the proposed solution to determine the UAS's pose. If an initial approximation is available, Li-Chee-Ming and Armenakis (2013) propose a viable solution to refine the navigation solution.

Related Work

Different solutions have been proposed to this model-to-image registration problem, Treiber (2010), Chin and Dyer (1986), and Besl and Jain (1985) provide a comprehensive survey. Among them is the geometric hashing technique (Gavrilla and Groen, 1992), an algorithm used in computer vision to match features against a database of such features. It is a highly efficient technique as matching is possible even when

Geomatics Engineering, Department of Earth and Space Science and Engineering, Lassonde School of Engineering, York University, 4700 Keele Street, Toronto, Ontario, M3J 1P3 Canada (julienli@yorku.ca).

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1117–1128.
0099-1112/14/8012–1117

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

Multi-UAV Surveillance over Forested Regions

Vengatesan Govindaraju, Gerard Leng, and Zhang Qian

Abstract

S-UAVs (Small-Unmanned Aerial Vehicles) have emerged as low-cost alternatives for aerial surveillance over forests. However, they provide limited coverage owing to their low altitudes and short endurance. Therefore, a quick and effective surveillance necessitates optimal flying paths, maximizing ground visibility. Even though the occlusion of ground points due to vegetation is significant in forests, it is generally neglected. This paper proposes a probabilistic sensing model that incorporates both occlusions due to terrain and vegetation, in the visibility computations and presents a two-step approach to determine near-optimal flight paths: (a) waypoints are strategically deployed to enhance visibility, using centroidal Voronoi tessellation, and (b) flyable paths are designed using a clustered spiral-alternating algorithm. Simulation studies conducted on synthetic terrains and a reconstructed terrain, from satellite data of tree-cover and a Digital Elevation Model (DEM), show the effectiveness of the proposed method in improving the terrain visibility as compared to commonly used grid-based waypoints.

Introduction

The recent advancements, in artificial intelligence and mechatronics, have boosted the application of autonomous Small Unmanned Aerial Vehicles (S-UAVs) to relieve humans from performing some dull, dirty, and dangerous tasks. S-UAVs are a class of unmanned aerial vehicles that are small enough for easy field deployment/recovery and transport (Watts *et al.* 2012). They were used predominantly in the military for surveillance and reconnaissance purposes. There has been a growing interest in the use of S-UAVs in civilian applications as well, due to their low operational costs and their inherent ability to reach areas that are inaccessible by humans or ground robots. For example, forests, due to its highly random and dense obstructions, become an important operating domain for S-UAVs, for a wide variety of applications such as environmental monitoring, wildlife tracking, anti-poaching operations, monitoring forest fires, and search-and-rescue (Nonami *et al.* 2010). Surveillance of forests with existing methods, such as remote sensing using either satellites or manned aircrafts, do not provide the desired spatial and temporal resolution and are also not cost-effective. The autonomous S-UAVs can provide real-time, high-resolution images of the forested regions and do not need skilled operators (Koh and Wich, 2012). However, they are generally electric powered with a short endurance of 0.5 to ~2 hours, have low flying speeds, and have low flying altitudes (<200 m) (Gundlach, 2012). These drawbacks imply that S-UAVs can cover only a limited area, in a single flight time. Therefore, an effective surveillance over large forest areas maximizes coverage by optimizing the imaging path for the S-UAV.

In order to optimize the imaging path for effective surveillance, the factors affecting the coverage must be studied. The term "coverage" here, means the Line-of-Sight visibility of the ground points as seen from the S-UAV's sensor. Since S-UAVs cannot support heavy payload, lightweight electro-optical sensors, such as visible or near-infra-red cameras, are commonly used. These sensors have a limited field of view and rely only on the direct line-of-sight visibility with the target to record the observation. In a forested environment, the field of view of these on-board sensors can get occluded in the presence of two types of obstructions: "Complete obstructions" due to terrain features and "partial obstructions" due to vegetation. Current methods for visibility computations consider only the complete obstructions such as terrain undulations or buildings. They either completely omit or overestimate the partial obstruction due to vegetation, to avoid the difficulty of incorporating discrete and stochastic variables in the visibility computations (Bartie *et al.* 2011). However, in a forested environment, vegetation is the major obstruction that cannot be neglected in the visibility computations, especially for low-flying S-UAV. This paper presents a probabilistic sensor model that incorporates both the complete and partial obstructions in the visibility computations from the UAV to maximize the ground visibility.

To improve the effectiveness of the surveillance, a near-optimal imaging path is designed in two steps: First, the waypoints (which are also the observation points), are strategically deployed using the method of centroidal Voronoi tessellations; second, a flyable path along the waypoints, which obeys the kinematic constraints of the S-UAV, is designed based on the improved Clustered Spiral-Alternating algorithm. Simulations are done on both the synthetically generated terrain and reconstructed terrain from actual satellite data. The simulations help to compare the resulting visibility of the proposed approach with the commonly used grid-based distribution of waypoints. This paper is organized as follows: The literature relevant to this field of research is addressed followed by a description of the proposed approaches, such as the visibility decay, the probabilistic sensor model, the waypoints determination using centroidal Voronoi tessellation and the path-planning using the Clustered Spiral-Alternating algorithm. The next Section presents the simulation results and compares the visibility values of the proposed approach with the visibility values of the grid-based approach, followed by the conclusions and some suggested future work to be done in this area.

Relevant Literature

The problem of finding a shortest path, that also satisfies some visibility requirements, has been well studied in the field of computational geometry in the name of "Watchman Routing

Mechanical Engineering Department, National University of Singapore, Block E1, 1 Engineering Drive 2, #02-01, Dynamics Lab, Singapore 117576 (vengatesan@u.nus.edu).

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1129–1137.
0099-1112/14/8012–1129

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

ASPRS Code of Ethics

Honesty, justice, and courtesy form a moral philosophy which, associated with mutual interest among people, should be the principles on which ethics are founded.

Each person who is engaged in the use, development, and improvement of the mapping sciences (Photogrammetry, Remote Sensing, Geographic Information Systems, and related disciplines) should accept those principles as a set of dynamic guides for conduct and a way of life rather than merely for passive observance. It is an inherent obligation to apply oneself to one's profession with all diligence and in so doing to be guided by this Code of Ethics.

Accordingly, each person in the mapping sciences profession shall have full regard for achieving excellence in the practice of the profession and the essentiality of maintaining the highest standards of ethical conduct in responsibilities and work for an employer, all clients, colleagues and associates, and society at large, and shall . . .

1. Be guided in all professional activities by the highest standards and be a faithful trustee or agent in all matters for each client or employer.

2. At all times function in such a manner as will bring credit and dignity to the mapping sciences profession.

3. Not compete unfairly with anyone who is engaged in the mapping sciences profession by:

   a. Advertising in a self-laudatory manner;

   b. Monetarily exploiting one's own or another's employment position;

   c. Publicly criticizing other persons working in or having an interest in the mapping sciences;

   d. Exercising undue influence or pressure, or soliciting favors through offering monetary inducements.

4. Work to strengthen the profession of mapping sciences by:

   a. Personal effort directed toward improving personal skills and knowledge;

   b. Interchange of information and experience with other persons interested in and using a mapping science, with other professions, and with students and the public;

   c. Seeking to provide opportunities for professional development and advancement of persons working under his or her supervision;

   d. Promoting the principle of appropriate compensation for work done by person in their employ.

5. Undertake only such assignments in the use of mapping sciences for which one is qualified by education, training, and experience, and employ or advise the employment of experts and specialists when and whenever clients' or employers' interests will be best served thereby.

6. Give appropriate credit to other persons and/or firms for their professional contributions.

7. Recognize the proprietary, privacy, legal, and ethical interests and rights of others. This not only refers to the adoption of these principles in the general conduct of business and professional activities, but also as they relate specifically to the appropriate and honest application of photogramme try, remote sensing, geographic information systems, and related spatial technologies. Subscribers to this code shall not condone, promote, advocate, or tolerate any organization's or individual's use of these technologies in a manner that knowingly contributes to:

   a. deception through data alteration;

   b. circumvention of the law;

   c. transgression of reasonable and legitimate expectation of privacy.

Retrieval of Spectral Reflectance of High Resolution Multispectral Imagery Acquired with an Autonomous Unmanned Aerial Vehicle: AggieAir™

Bushra Zaman, Austin Jensen, Shannon R. Clemens, and Mac McKee

Abstract

This research presents a new semi-automatic model for converting raw AggieAir™ footprints in visible and near-infrared (NIR) bands into reflectance images. AggieAir, a new unmanned aerial vehicle (UAV) platform, is flown autonomously using pre-programmed flight plans at low altitudes to limit atmospheric effects. The UAV acquires high-resolution, multispectral images and has a flight duration of about 30 minutes. The sensors on board are twin cameras with duplicate settings and automatic mode disabled. A white Barium Sulfate (BaSO4) panel is used for reflectance calibration and in situ irradiance measurements. The spatial resolution of the imagery is 25 cm; the radiometric resolution is 8-bit. The raw images are mosaicked and orthorectified and the model converts their digital numbers (DN) to reflectance values. Imagery, acquired around local solar noon over wetlands on the Great Salt Lake, Utah, is used to illustrate the results. The model generates high quality images and the results are good. The reflectance values of vegetation in the NIR, Green and Red bands extracted at the test locations are consistent. The image processing, reflectance calculations, accuracy issues, with the proposed method are discussed.

Introduction

In the recent past, various unmanned aerial vehicle (UAV) platforms equipped with a myriad of devices have been used to gather data in different bands for an array of applications. It is an area of remote sensing that has become very active, and UAVs are rapidly becoming the preferred platform for development of remote sensing applications (Watts *et al.,* 2012). Earth orbiting satellites and manned aircraft remote sensors have the advantage of covering large areas, but the high operating cost of such instruments limits the availability of timely information for specific areas of interest (Hakala *et al.*, 2010). Remote sensing applications require more sustainable, affordable, user-friendly systems which are compliant with various levels of changes in technology. Zhang and Kovacs (2012) state that low altitude remote sensing platforms, or UAVs address most of these issues, and can be a potential alternative to satellite imagery given their low cost of operation, high spatial and temporal resolution, and flexibility in image acquisition programming. UAV imagery provides the ability to quantify spatial patterns, and is used in rangeland monitoring and mapping to quantify patches of vegetation and soil not detectable with piloted aircraft or satellite imagery (Laliberte and Rango, 2009). UAV data have been extensively used in forest fire applications (Merino *et al.*, 2006, Ambrosia *et al.*, 2003), wetland management and riparian applications (Zaman *et al.,* 2011, Jensen *et al.*, 2011), precision agriculture (Primicerio *et al.*, 2012), agricultural decision support (Herwitz *et al.*, 2004). Field reflectance data from UAV platforms are also increasingly being used for image classification and predictive models (Berni *et al.*, 2009). But the accuracy issues related with conversion of the information acquired by the sensors on board these UAVs into useful data remains a widely discussed topic. The small UAV systems have low payload capabilities and are commonly equipped with lightweight, low-cost digital cameras, which may complicate the image processing procedures. Additionally, the chemical basis for making a filter used on these cameras is proprietary and there is variation in filter spectral transmittances among various digital cameras (Hunt *et al.*, 2010), which calls for a specific radiometric and geometric calibration (Hruska *et al.,* 2012) to produce reliable data. Several UAV imaging systems require custom designed applications for photogrammetric processing and creation of orthomosaics to handle the large number of small-footprint images acquired by the UAVs with a rather unstable platform (Du *et al.,* 2008; Laliberte and Rango, 2008; Wilkinson *et al.*, 2009). This paper discusses processing of data obtained from a new UAV system, AggieAir™, which uses off-the-shelf Canon PowerShot SX100 cameras as sensors.

UAV imagery has spectral information in the form of digital numbers which have noise arising from changing view, illumination geometry, and instrument errors. Huang *et al.*, 2002 demonstrate the necessity of converting DN to at-satellite reflectance when atmospheric correction is not feasible. DN is a function not only of land-cover, but also of the sensor calibration, solar zenith angle, sensor viewing angle, seasonally variable Earth/Sun distance, and diurnally variable atmospheric conditions (Slater, 1980). Exposure settings on the digital camera are chosen based on overall light intensity, which varies over time with changes in solar elevation, atmospheric transmittance, and clouds (Gates, 2003). Consequently, it is desirable to convert DN to reflectance values that correct for these changes (Hunt *et al.*, 2005). Surface reflectance value has become the vital measurement required for most remote sensing models (Moran *et al.*, 2001). Laliberte *et al.* (2011) state that a UAS-based image acquisition system produces hundreds of very high resolution small footprint images that require geometric and radiometric corrections and subsequent mosaicking for use in a Geographic Information System (GIS) and extraction of meaningful data. Similarly Jensen *et al.* (2010) discuss the necessity of calibration of UAV imagery and navigation sensors.

UWRL 247, Utah Water Research Laboratory, College of Engineering. 1600 East Canyon Road, Logan, UT 84321 (b.zaman@aggiemail.usu.edu).

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1139–1150.
0099-1112/14/8012–1139

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

Modeling Above-Ground Biomass in Tallgrass Prairie Using Ultra-High Spatial Resolution sUAS Imagery

Chuyuan Wang, Kevin P. Price, Deon van der Merwe, Nan An, and Huan Wang

Abstract

We examined the relationship between tallgrass above-ground biomass (AGB) and NDVI from ultra-high spatial resolution multispectral imagery collected by small unmanned aircraft systems (sUAS). This study was conducted at the Tallgrass Prairie National Preserve in Chase County, Kansas. Results show that NDVI values computed from sUAS imagery explained up to 94 percent of the variance (p <0.01) in AGB measurements. The model coefficient of determination (r^2) decreased with increasing aircraft flight altitude suggesting image spatial resolution is a key factor influencing the strength of the relationship. A scaling-up approach from small-scale sUAS imagery to broad-scale, digital aerial imagery collected at 1,200 meters by a piloted aircraft was used to provide AGB model estimates across the entire 4,500 ha of the Preserve. Spectral reflectance data measured by spectroradiometer were also used to identify three optimal regions of the spectrum that have the highest significant correlations with tallgrass AGB.

Introduction

The tallgrass prairie ecosystem is native in the Great Plains of central North America that is among the most species diverse and productive warm-season grassland ecosystems (Knapp *et al.*, 1998; Knapp and Seastedt, 1998). The tallgrass prairie once covered a large portion of the American Midwest, but today less than 4 percent of the North American tallgrass prairie remains due to intensive cultivation, over grazing, and urban sprawl. It has become one of the most endangered and rarest ecosystems in the world (Samson and Knopf, 1994; Steinauer and Collis, 1996). The largest contiguous area of tallgrass prairie now can only be found in the Flint Hills that mostly resides in the State of Kansas. The existing and converted tallgrass prairie, together with other types of prairie ecosystems in the Central Great Plains, covers about 40 percent of Kansas and produces billions of dollars in grazing livestock each year (USDA, 2007). It is therefore essential to both nature conservation and agriculture in Kansas.

Above-ground biomass (AGB) is an important ecological indicator for understanding the tallgrass prairie ecosystem health. It is of critical importance to the proper management and understanding of climatic and anthropogenic influences on the tallgrass prairie ecosystem in the Central Great Plains (Lauenroth, 1979; Seaquist *et al.*, 2003; An *et al.*, 2013). Accurate AGB measurements and estimations can be used to predict secondary production in a tallgrass ecosystem, such as livestock yield, and to better understand the rangeland properties so that conservation of tallgrass prairie natural resources could be improved.

Various means of measuring and predicting grassland AGB have been developed, but they all have certain level of limitations. The traditional method involving field-based measurements is very time-consuming and labor-intensive. Examples of studies involving traditional approaches can be found in Briggs and Knapp (1995); Briggs *et al.* (2005); Reed *et al.* (2005); Nippert *et al.* (2006); Heisler-White *et al.* (2008); Craine *et al.* (2010); and La Pierre *et al.* (2011). The challenge of using these more traditional field-based biomass harvest methods is that it is only practical for a relatively small geographic area. Predicting AGB for the entire tallgrass prairie ecosystem is not possible using these methods.

Physical-based models that incorporate climatic attributes and environmental factors as variables, such as annual mean precipitation, mean air temperature, mean soil temperature, soil water-holding capacity, and topographic position, to predict grassland biomass and productivity have also been investigated (Towne and Owensby, 1984; Sala *et al.*, 1988; Briggs and Knapp, 1995; Nippert *et al.*, 2006; La Pierre *et al.*, 2011). Physical-based models may work well for other ecosystems, but mixed results and variable findings have been reported in the cited studies that focus on the tallgrass prairie ecosystem in the Central Great Plains (An *et al.* 2013). It is because native tallgrass species in the Central Great Plains have adapted to severe drought conditions and can extract soil moisture at considerable depths (Brown and Bark, 1971), thus rendering drier conditions less of an influencing factor depending on the site location (Weaver and Albertson, 1943). Also the conversion of climatic attributes and environmental factors to spatial and temporal variables is not error free. Therefore, those important variables in physical-based models are not necessarily the best predictors for tallgrass prairie in the Central Great Plains.

For reasons discussed above, some scientists have turned to the use of satellite remotely sensed data to measure and predict grassland AGB and productivity at the regional and global scales (Tucker, 1985; Asrar *et al.*, 1985; Wylie *et al.*,

Chuyuan Wang is with the Department of Geography, Kansas State University, Manhattan, Kansas.

Kevin P. Price is with the Department of Agronomy, Kansas State University, Manhattan, Kansas; and the Department of Geography, Kansas State University, Manhattan, Kansas (kevin@roboflight.com).

Deon van der Merwe is with the College of Veterinary Medicine, Kansas State University, Manhattan, Kansas.

Nan An and Huan Wang are with the Department of Agronomy, Kansas State University, Manhattan, Kansas.

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1151–1159.
0099-1112/14/8012–1151

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

APPLICATIONS PAPER

High Resolution Imagery Collection for Post-Disaster Studies Utilizing Unmanned Aircraft Systems (UAS)

Stuart M. Adams, Marc L. Levitan, and Carol J. Friedland

Abstract

This paper examines the use of unmanned aircraft systems (UAS) to capture imagery for use in post-disaster field studies at the neighborhood and individual building level. A discussion of post-disaster imagery collection including satellite, aerial, and ground-based platforms is first presented. Applications of UAS in recent disasters as described in the literature are then surveyed, and a case study investigating UAS capabilities for imagery collection following an EF-3 tornado in northern Alabama on 02 March 2012 is presented. Case study considerations include the multi-rotor unmanned aerial vehicle (UAV) equipment and ground station, onboard imagery devices, flight considerations and capabilities, and imagery and metadata collection capabilities of the UAS. Sample post-tornado imagery of building damage is shown, demonstrating the order of magnitude improvement in imagery resolution compared to traditional post-disaster aerial photography.

Introduction

Damage assessments following disaster events are often performed using imagery acquired through satellite, aerial, and ground-based (vehicle-mounted and handheld) platforms, which can be analyzed using visual, spectral, and photogrammetric techniques. Satellite and aerial imagery covers large geographical areas but are of limited use for detailed investigations of individual buildings and neighborhoods due to spatial resolution limitations. Additionally, while such imagery is usually available following large disasters such as the Joplin, Missouri, tornado in 2011 and Hurricane Sandy in 2012, it may not be readily available following smaller events.

Imagery for use in studies of the performance of the built environment at individual building and neighborhood levels has mainly been obtained by handheld and, more recently, vehicle-mounted cameras. A significant limitation of vehicle-mounted systems is that they are best at collecting images of the street facing side(s) of the building. Side views may or may not be available depending on proximity of adjacent buildings, and views of the rear face of the building are generally not available unless the neighborhoods have alleys. Trees, shrubs, and fences create interference for vehicle-mounted cameras. These elements can also create interference for handheld cameras, but to a lesser extent than the aforementioned obstacles since the photographer has more flexibility in selecting a vantage point. When access to a damaged building is possible, handheld cameras are often used to acquire imagery inside the building and from the roof of the building, to obtain a much fuller understanding of the damage. Imagery collected from the roof, especially roofs of taller buildings, can show damage to adjacent buildings as well. However, in some instances, buildings are too damaged to enter safely. Ground-based imagery acquisition (both handheld and vehicle-based) can be hindered by site access limitations, including: downed trees, power lines, and other debris blocking the roads; roads washed out by storm surge or inland flooding; law enforcement roadblocks; private property and privacy considerations; and physical security considerations for the ground-based damage survey team.

The limitations of existing satellite, aerial, and ground-based imagery platforms also create difficulties when assessing building damage caused by different hazards. For example, storm surge damage to the walls and interior of a building in cases where the roof remained intact may not be visible from nadir (vertical) satellite and aerial imagery. Earthquake-induced collapses where the roof remains largely intact may similarly be difficult to identify from nadir imagery (Gerke and Kerle, 2011). Wind damage to flat or low slope roofs may not be observable from ground based imagery. Additional information on capabilities and limitations of the different imagery platforms are discussed by Adams *et al.* (2010).

Recent advances in UAS flight and flight control capabilities and in digital camera technologies, coupled with substantial reductions in the costs of both, have positioned UAS as platforms of interest for post-disaster studies. UAS provide a user-controlled means to collect imagery from multiple angles at neighborhood and individual building scales. UAV-mounted camera systems have the capability to capture still and video imagery from vertical and oblique perspectives at much higher resolutions than currently available from commercial satellite and aerial photography (Nebiker *et al.*, 2008). UAS also have capabilities to overcome common site access and image collection limitations of ground-based platforms. UAS platforms can thus potentially fill a significant gap in current

Stuart M. Adams is with the Department of Civil and Environ-mental Engineering, Louisiana State University, 3418 Patrick F. Taylor Hall, Baton Rouge, LA 70803 (sadam15@lsu.edu).

Marc L. Levitan is with the National Windstorm Impact Reduction Program, Engineering Laboratory, National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD, 20899 (marc.levitan@nist.gov).

Carol J. Friedland is with Bert S. Turner Department of Con-struction Management, Louisiana State University, 3128

Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 12, December 2014, pp. 1161–1168.
0099-1112/14/8012–1161

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

MEMBERS/SUBSCRIBERS

When you are logged into the ASPRS website, go to this page:

http://www.asprs.org/Photogrammetric-Engineering-and-Remote-Sensing/2014-E-Journal-Members.html

Under **PE&RS E-Journal Edition** you will see the paragraph:

As a member or subscriber you have full access to the peer reviewed articles, hosted by MetaPress. **Please click here to access PE&RS peer reviewed articles in both the current issue and ten year's worth of back issues of the journal.**

Click on either of the links in that paragraph (from the web page, not this page) to access the peer-reviewed articles.

NON-MEMBERS/NON-SUBSCRIBERS

Go to http://www.asprs.org/Join-Now.html to learn how to become a member and access peer-reviewed content

WHO'S WHO IN ASPRS

BOARD OF DIRECTORS

OFFICERS

President A. Stewart Walker*
BAE Systems
stewart.walker2@baesystems.com

President-Elect E. Lynn Usery*
U.S. Geological Survey
usery@usgs.gov

Vice President Charles Toth*
OSU Center for Mapping
toth@cfm.ohio-state.edu

Past President Stephen D. DeGloria*
Cornell University
sdd4@cornell.edu

Treasurer Donald T. Lauer*
U.S. Geological Survey (Emeritus)
lauerdc@gmail.com

BOARD MEMBERS

Alaska Region - 2016
Nicholas William Hazelton
University of Anchorage
nwjh@mac.com
www.asprs.org/All-Regions/Alaska.html

Central New York Region - 2017
Jason Smith
ITT Exelis - Geospatial Systems
jason.smith@exelisinc.com
www.asprs.org/All-Regions/Central-New-York.html

Columbia River Region - 2017
Marcus Glass
3Di
mglass@3dimapping.com
www.asprs.org/All-Regions/Columbia-River.html

Eastern Great Lakes Region - 2017
Srinivasan Dharmapuri
Michael Baker International
dssrini@gmail.com
www.asprs.org/All-Regions/Eastern-Great-Lakes.html

Florida Region - 2016
Thomas J. Young
Pickett & Associates
jyoung@pickett-inc.com
www.asprs.org/All-Regions/Florida.html

Geographic Information Systems Division - 2015
David Alvarez,* CMS, GISP
Woolpert
david.alvarez@woolpert.com
www.asprs.org/Divisions/GIS-Division.html

Heartland Region - 2015
David W. Kreighbaum*
NGA
David.W.Kreighbaum@nga.mil
www.asprs.org/All-Regions/Heartland.html

Intermountain Region - 2016
Lucinda A. Clark
Draper, UT 84020
cindyc1952@gmail.com
www.asprs.org/All-Regions/Intermountain.html

Lidar Division - 2016
Christopher Parrish
NOAA
chris.parrish@uwalumni.com
www.asprs.org/Divisions/Lidar-Division.html

Mid-South Region - 2016
Haluk Cetin
Murray State University
haluk.cetin@murraystate.edu
www.asprs.org/All-Regions/Mid-South.html

New England Region - TBA
www.asprs.org/All-Regions/New-England.html

North Atlantic Region - 2016
John Trunkwalter
BAE Systems
john.trunkwalter@baesystems.com
www.asprs.org/All-Regions/North-Atlantic.html

Northern California Region-2015
Lorraine Amenda
Towill, Inc.
Lorraine.Amenda@towill.com
www.asprs.org/All-Regions/Northern-California.html

Photogrammetric Applications Division - 2016
Robert Thomas
Integrity Applications, Inc.
rthomas@integrity-apps.com
www.asprs.org/Divisions/Photogrammetric-Applications-Division.html

Potomac Region - 2017
Barbara A. Eckstein
L-1 MCCLENDON
beckstein@surfbest.net
www.asprs.org/All-Regions/Potomac.html

Primary Data Acquisition Division - 2017
Pierre le Roux
Quantum Spatial
pleroux@quantumspatial.com
www.asprs.org/Divisions/Primary-Data-Aquisition-Division.html

Professional Practice Division - 2016
Michael Zoltek
Pictometry International Corp.
mike.zoltek@pictometry.com
www.asprs.org/Divisions/Professional-Practice-Division.html

Puget Sound Region - 2015
Terry A. Curtis
WA DNR, Resource Map Sect.
terry.curtis@wadnr.gov
www.asprs.org/All-Regions/Puget-Sound.html

Remote Sensing Applications Division - 2016
James Stuart Blundell
Exelis Visual Information Systems
Stuart.Blundell@exelisvis.com
www.asprs.org/Divisions/Remote-Sensing-Applications-Division.html

Rocky Mountain Region - 2015
Jeffrey M. Young*
Centennial, CO 80115
jeffreymyoung@msn.com
www.asprs.org/All-Regions/Rocky-Mountain.html

Southwest US Region - 2017
Steven Lambert, CP
Esri, Inc
slambert@esri.com
www.asprs.org/All-Regions/Southwest-US.html

Sustaining Members Council Chair – 2015
Brian E. Murphy
Northrop Grumman Information Systems
brian.murphy@ngc.com
www.asprs.org/About-Us/Sustaining-Members-Council.html

Western Great Lakes Region - 2016
Douglas Fuller*
Sheboygan, WI 53081
FullerDoug@charter.net
www.asprs.org/All-Regions/Western-Great-Lakes.html

DIVISION OFFICERS

Geographic Information Systems
Director: David Alvarez
Assistant Director: Matthew D. Dunbar
University of Washington
mddunbar@uw.edu
www.asprs.org/Divisions/GIS-Division.html

Lidar
Director: Christopher E. Parrish
Assistant Director: Jason Stoker
USGS
jstoker@usgs.gov
www.asprs.org/Divisions/Lidar-Division.html

Photogrammetric Applications
Director: Robert D. Thomas
Assistant Director: Scott Perkins
Surveying And Mapping (SAM) LLC
sperkins@sam.biz
www.asprs.org/Divisions/Photogrammetric-Applications-Division.html

Primary Data Acquisition
Director: Pierre le Roux
Assistant Director: TBD
www.asprs.org/Divisions/Primary-Data-Aquisition-Division.html

Professional Practice
Director: Michael J. Zoltek
Assistant Director: Frank Taylor
Midwest Aerial Photography
frank@midwestaerialphoto.com
www.asprs.org/Divisions/Professional-Practice-Division.html

Remote Sensing Applications
Director: James Stewart Blundell
Assistant Director: John McCombs
NOAA Coastal Services Center
john.mccombs@noaa.gov
www.asprs.org/Divisions/Remote-Sensing-Applications-Division.html

SUSTAINING MEMBERS COUNCIL

Chair: Brian Murphy
Vice Chair: Brenda S. Burroughs
Optech International
brendab@optechint.com
http://www.asprs.org/About-Us/Sustaining-Members-Council.html

STUDENT ADVISORY COUNCIL

Chair: Patrick Adda
University of New Brunswick
padda@unb.ca
Deputy Chair: Mingshu Wang
University of Georgia
mswang@uga.edu
http://www.asprs.org/Students/Student-Advisory-Council.html

*Executive Committee Member

3D Laser Mapping LTD
Bingham, Nottingham, United Kingdom
www.3dlasermapping.com
Member Since: 2/2010

Aerial Cartographics of America, Inc. (ACA)
Orland, Florida
www.aca-net.com
Member Since: 10/1994

Aerial Services, Inc.
Cedar Falls, Iowa
www.AerialServicesInc.com
Member Since: 5/2001

Aero-Graphics, Inc.
Salt Lake City, Utah
www.aero-graphics.com
Member Since: 4/2009

AeroTech Mapping Inc.
Las Vegas, Nevada
www.atmlv.com
Member Since: 8/2004

Aerovel Corporation
White Salmon, Washington
www.aerovelco.com
Member Since: 10/2014

Acute3D
Sophia Antipolis, Cedex, France
www.acute3d.com
Member Since: 4/2014

The Airborne Sensing Corporation
Toronto, Ontario, Canada
www.airsensing.com
Member Since: 1/2013

AGFA Materials Corporation
Goose Creek, South Carolina
www.agfa.com
Member Since: 1/1990

Air Photographics, Inc.
Martinsburg, West Virginia
www.airphotographics.com
Member Since: 1/1973

Altavian
Gainesville, Florida
www.altavian.com
Member Since: 2/2014

American Surveyor Magazine
Frederick, Maryland
www.TheAmericanSurveyor.com
Member Since: 12/2004

Applanix
A Trimble Company
Ontario, Canada
www.applanix.com
Member Since: 7/1997

Axis GeoSpatial, LLC
Easton, Maryland
www.axisgeospatial.com
Member Since: 1/2005

Ayres Associates, Inc.
Madison, Wisconsin
www.AyresAssociates.com
Member Since: 1/1953

BAE Systems
San Diego, California
www.baesystems.com/gxp
Member Since: 7/1995

BNP Media, Point of Beginning Magazine
(formally POB Magazine)
Troy, Michigan
www.bnpmedia.com
Member Since: 7/2006

Bohannan Huston, Inc.
Albuquerque, New Mexico
www.bhinc.com
Member Since: 11/1992

Cardinal Systems, LLC
Flagler Beach, Florida
www.cardinalsystems.net
Member Since: 1/2001

Certainty 3D LLC
Orlando, Florida
www.certainty3d.com
Member Since: 11/2012

COL-EAST, Inc.
North Adams, Massachusetts
www.coleast.com
Member Since: 1/1976

CompassData, Inc.
Centennial, Colorado
www.compassdatainc.com
Member Since: 3/2014

CRC Press - Taylor & Francis Group
Boca Raton, Florida
www.crcpress.com
Member Since: 9/2006

CRITIGEN
(formerly CH2M HILL)
Redding, California
www.critigen.com
Member Since: 1/1974

DAT/EM Systems International
Anchorage, Alaska
www.datem.com
Member Since: 1/1974

Dewberry
Fairfax, Virginia
www.dewberry.com
Member Since: 1/1985

DigitalGlobe
Longmont, Colorado
www.digitalglobe.com
Member Since: 7/1996

DMC International Imaging Ltd.
Guildford, Great Britain
www.dmcii.com
Member Since: 3/2008

Dynamic Aviation Group, Inc.
Bridgewater, Virginia
www.dynamicaviation.com
Member Since: 4/2003

Eagle Mapping, Ltd
British Columbia, Canada
www.eaglemapping.com
Member Since: 1/1999

Eastern Topographics
Wolfeboro, New Hampshire
www.e-topo.com
Member Since: 8/1978

Elecnor Deimos Imaging
Boecillo - Valladolid, Spain
www.deimos-imaging.com
Member Since: 1/2014

Environmental Research Incorporated
Linden, Virginia
www.eri.us.com
Member Since: 8/2008

Esri Research Institute, Inc.
Redlands, California
www.esri.com
Member Since: 1/1987

EXELIS
Boulder, Colorado
www.exelisvis.com
Member Since: 1/1997

Flatdog Media, Inc./Professional Surveyor Magazine
(formally Reed Business-Geo)
Frederick, Maryland
www.profsurv.com
Member Since: 1/1998

Fugro EarthData, Inc.
(formally EarthData, Inc.)
Frederick, Maryland
www.earthdata.com
Member Since: 1/1994

GeoBC
Victoria, Bristish
www.geobc.gov.bc.ca
Member Since: 12/2008

GEOconnexion International
Cambridge, United Kingdom
www.geoconnexion.com
Member Since: 11/2011

GeoCue Corporation
(formerly NIIRS10, Inc.)
Madison, Alabama
info@geocue.com
Member Since: 10/2003

Geolas Consulting
Poing, Germany
www.geolas.com
Member Since:1/2002

Global Science & Technology, Inc.
Greenbelt, Maryland
www.gst.com
Member Since: 10/2010

GRW Aerial Surveys, Inc.
Lexington, Kentucky
www.grwinc.com
Member Since: 1/1985

HyVista Corporation
Castle Hill, Australia
www.hyvista.com
Member Since: 3/2010

ICAROS, Inc.
Fairfax, Virginia
www.lcaros.us
Member Since: 2/2013

SUSTAININGMEMBERS

Intergraph (ERDAS Inc.)
Norcross, Georgia
www.intergraph.com/geospatial
Member Since: 1/1985

Keystone Aerial Surveys, Inc.
Philadelphia, Pennsylvania
www.keystoneaerialsurveys.com
Member Since: 1/1985

KLT Associates, Inc.
Peabody, Massachusetts
www.kltassoc.com
Member Since: 11/1993

Kucera International
Willoughby, Ohio
www.kucerainternational.com
Member Since: 1/1992

Lead'Air, Inc.
(formerly Track'air BV)
Kissimmee, Florida
www.trackair.com
Member Since: 6/2001

LizardTech
Seattle, Washington
www.lizardtech.com
Member Since: 10/1997

Magnolia River Geospatial
(formerly Aeroquest Optimal, Inc./Optimal Geomatics)
Huntsville, Alabama
www.magnolia-river.com
Member since: 2/2006

MDA Information Systems LLC
(formerly MDA Federal Inc.)
Gaithersburg, Maryland
www.mdaus.com
Member Since: 1/1993 (rejoined in 2011)

Merrick & Company
Greenwood Village, Colorado
www.merrick.com/gis
Member Since: 4/1995

Michael Baker Jr., Inc.
Beaver, Pennsylvania
www.mbakercorp.com
Member Since: 1/1950

Microsoft UltraCam Team (Vexcel Imaging, GmbH)
Graz, Austria
www.microsoft.com/ultracam
Member Since: 6/2001

NGA-National Geospatial-Intelligence Agency
Springfield, Virginia
https://www.nga.mil
Member Since: 11/2008

NASA Earth Science Division
Washington, DC
www.appliedsciences.nasa.gov
Member Since: 1/2001

NOAA National Geodetc Survey
Silver Spring, Maryland
www.ngs.noaa.gov
Member Since: 7/2009

NorPix, Inc.
Montreal, Quebec, Canada
www.norpix.com
Member Since: 1/2012

North West Group
Calgary, Canada
www.nwgeo.com
Member Since: 1/1998

NSTec, Remote Sensing Laboratory
Las Vegas, Nevada
www.nstec.com
Member Since: 7/2005

Observera, Inc.
Chantilly, Virginia
www.observera.com
Member Since: 7/1995

Optech Incorporated
Toronto, Canada
www.optech.ca
Member Since: 1/1999

PANalytical NIR
(formerly ASD)
Boulder, Colorado
www.asdi.com
Member Since: 1/1998

PCI Geomatics
Richmond Hill, Ontario, Canada
www.pcigeomatics.com
Member Since: 1/1989

Pickett & Associates, Inc.
Bartow, Florida
www.pickett-inc.com
Member Since: 4/2007

Pictometry International Corp.
Rochester, New York
www.pictometry.com
Member Since: 5/2003

Quantum Spatial, Inc. (Quantum Spatial)
(formerly AeroMetric, Inc.)
Sheboygan, Wisconsin
www.aerometric.com
Member Since: 1/1974

Riegl USA, Inc.
Orlando, Florida
www.rieglusa.com
Member Since: 11/2004

Robinson Aerial Survey, Inc. (RAS)
Hackettstown, New Jersey
www.robinsonaerial.com
Member Since: 1/1954

Sanborn
Colorado Springs, Colorado
www.sanborn.com
Member Since: 9/1984

Science Applications International Corporation
Mc Lean, Virginia
www.saic.com
Member Since: 1/1987

The Sidwell Company
St. Charles, Illinois
www.sidwellco.com
Member Since: 1/1973

SimActive, Inc.
Montreal, Quebec, Canada
www.simactive.com
Member Since: 1/2010

Spectral Evolution
North Andover, Massachusetts
www.spectralevolution.com
Member Since: 10/2010

Surveying and Mapping (SAM), Inc.
Austin, Texas
www.saminc.biz
Member Since: 12/2005

Trimble
Westminster, Colorado
www.trimble.com
Member Since: 4/1994

Towill, Inc.
San Francisco, California
www.towill.com
Member Since: 1/1952

U.S. Geological Survey
Reston, Virginia
www.usgs.gov
Member Since: 4/2002

University of Twente/Faculty ITC
[formerly International Institute for Geo-Information Science and Earth Observation (ITC)]
Enschede, Netherlands
www.itc.nl
Member Since: 1/1992

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

Visual Intelligence Systems, LP
Houston, Texas
www.visualintelligenceinc.com
Member Since: 4/2014

Wilson & Company, Inc., Engineers & Architects
Albuquerque, New Mexico
www.wilsonco.com
Member Since: 3/2007

Wiser Company, LLC
Murfreesboro, Tennessee
www.wiserco.com
Member Since: 7/1997

Woolpert LLP
Dayton, Ohio
www.woolpert.com
Member Since: 1/1985

XEOS Imaging Inc.
Quebec, Canada
www.xeosimaging.com
Member Since: 11/2003

Photogrammetric Engineering and Remote Sensing (*PE&RS*)

Instructions for Authors Submitting a Manuscript for Peer Review

Authors submitting a new manuscript for peer review should follow these instructions. Failure to do so will result in the manuscript being returned to the author.

Introduction: The American Society for Photogrammetry and Remote Sensing (ASPRS) seeks to publish in *Photogrammetric Engineering & Remote Sensing* (*PE&RS*) theoretical and applied papers that address topics in photogrammetry, remote sensing, geographic information systems (GIS), the Global Positioning System (GPS) and/or other geospatial information technologies. Contributions that deal with technical advancements in instrumentation, novel or improved modes of analysis, or innovative applications of these technologies in natural and cultural resources assessment, environmental modeling, or the Earth sciences (atmosphere, hydrosphere, lithosphere, biosphere, or geosphere) are especially encouraged. In addition, papers dealing with the practical or applied aspects for these disciplines will be published as "Applications" papers (see additional instructions below).

Review Procedures: Manuscripts are peer reviewed and refereed by a panel of experts selected by the Editor. A double-blind review procedure is used. The identities and affiliations of authors are not provided to reviewers, nor are reviewers' names disclosed to authors. Our goal is to provide authors with completed reviews within 90 days of receipt of a manuscript by the Editor. Manuscripts accepted for publication will be returned to the author(s) for final editing before being placed in the queue for publication. Manuscripts not accepted will either be (1) rejected or (2) returned to the author(s) for revision and subsequent reconsideration by the review panel. Authors who do not revise and return a "to-be-reconsidered" manuscript within 90 days from receipt of reviews may have their manuscript withdrawn from the review process.

English Language: Authors whose first language is not English must have their manuscripts reviewed by an English-speaking colleague or editor to refine use of the English language (vocabulary, grammar, syntax). At the discretion of the Editor, manuscripts may be returned for English language issues before they are sent for review.

Cover Letter: All submissions must also include a separate cover letter. Please modify the sample Cover Letter found at http://www.asprs.org/pers/CoverLetter and then convert it to a PDF file. It is important that we have the full names and titles (Dr. Russell G. Congalton not R. G. Congalton), complete mailing addresses, and email addresses of all the authors and any special instructions about the paper. Papers can not be submitted for review until this information is received by the editor. Also, the paper must be original work and not currently being considered for publication in any other journal. Finally, the authors must pay for any color figures in the manuscript and any page charges for articles longer than 7 journal pages. (Details on color costs can be found at http://www.asprs.org/pers/ColorOrderForm.)

"Applications" Papers: A maximum of one "Applications" paper will be published each month as the last paper in the peer-reviewed section of PE&RS. The authors should follow all the instructions in this document. However, the "Applications" paper will be strictly limited to 7 journal pages. These papers will be peer-reviewed, but will emphasize the practical and applied aspects of our discipline. These papers must be identified by the author as an "Applications" paper in the cover letter and will be labeled as an "Applications" paper in the journal.

Preparing a Manuscript for Review: Authors must submit papers electronically in PDF format. Care must be taken to remove the author(s) name(s) from the electronic document. Please remove all author identification from the Properties of Microsoft Word before creating the PDF. Verify under Properties in Adobe Reader that your identity has been removed.

Format Requirements: Manuscripts submitted for peer review must be prepared as outlined below. Manuscripts that do not conform to the requirements described below will be returned for format revisions before they are sent for review.

1. **Typing:** All pages must be numbered at the bottom of the page. In addition, manuscripts must be single column and double-spaced. An 11 or 12-point font such as Times New Roman or Arial is preferred. Authors should use 8.5 by 11-inch or A4 International (210- by 297-mm) paper size, with 30-mm (1.25 inch) margins all around. For review purposes every part of the manuscript must be double-spaced, including title page/abstract, text, footnotes, references, appendices and figure captions. Manuscripts that are single-spaced or have no page numbers will be returned to authors.
2. **Paper Length:** Authors are encouraged to be concise. Published papers are generally limited to 7–10 journal pages. A 27-page manuscript (including tables and figures), when typed as indicated above, equals about 7 journal pages. Authors of published papers will be charged $125/page for each page exceeding 7 journal pages. These page charges must be paid before publication; without exception. (Details on page charges are included on the Offprint and Extra Page Order Form, available at http://www.asprs.org/PE-RS-Submissions-Policy-and-Guidelines/Offprint-Order-Form.html).
3. **Title/Abstract:** Authors should strive for titles no longer than eight to ten words. The first page of the paper should include the title, a one-sentence description of the paper's content to accompany the title in the *PE&RS* Table of Contents, and the abstract. To facilitate the blind review process, authors' names, affiliations, and addresses must be provided only in a separate cover letter, not on the title page. Authors should indicate both their current affiliation and, if different, their affiliation at the time the research was performed. Following the title and one-sentence and on the same page must be the abstract. All manuscripts submitted for peer review must include an abstract of 150 words or less. The abstract should include information on goals, methods and results of the research reported. The rest of the paper should begin on the second page.
4. **Figures and Tables:** All figures and tables must be cited in the text. Authors should note that figures and tables will usually be reduced in size by the printer to optimize use of space, and should be designed accordingly. For purposes of peer review, figures and tables can be embedded in the manuscript. However, it should be noted that papers, once accepted, will require that all figures be included as separate files (see instructions for accepted papers) If the manuscript contains copyrighted imagery, a copyright statement must be included in the caption (e.g., ©SPOT Image, Copyright [year] CNES).

5 **Color Illustrations:** Authors should use black and white illustrations whenever possible. Authors who include color illustrations will be charged for the cost of color reproduction. These costs must be paid before an article is published. Details on color costs can be found at http://www.asprs.org/pers/ColorOrderForm. Authors should indicate in the cover letter that they have the funds to pay for any color figures in their paper.

6 **Metric System:** The metric system (SI Units) will be employed throughout a manuscript except in cases where the English System has special merit stemming from accepted conventional usage (e.g., 9- by 9-inch photograph, 6-inch focal length). Authors should refer to "Usage of the International System of Units," *Photogrammetric Engineering & Remote Sensing*, 1978, 44 (7): 923-938.

7 **Equations:** Authors should express equations as simply as possible. They should include only those equations required by an average reader to understand the technical arguments in the manuscript. Manuscripts that appear to have excessive mathematical notation may be returned to the author for revision. Whenever possible, authors are encouraged to use the Insert and Symbol capabilities of Microsoft Word to build simple equations. If that is not possible, the author must indicate in the cover letter which software was used to create the equations. *Microsoft Equation, Microsoft Equation Editor, or MathType* format should be used only if absolutely necessary. Equations must be numbered, but unlike tables, figures, color plates, and line drawings should be embedded in the text file.

8 **References:** A complete and accurate reference list is essential. Only works cited in the text should be included. Cite references to published literature in the text in alphabetical order by authors' last names and date, as for example, Jones (1979), Jones and Smith (1979) or (Jones, 1979; Jones and Smith, 1979), depending on sentence construction. If there are more than two authors, they should be cited as Jones et al. (1979) or (Jones *et al*., 1979). Personal communications and unpublished data or reports should not be included in the reference list but should be shown parenthetically in the text (Jones, unpublished data, 1979). Format for references will be as follows:

Books:
Falkner, E., 1995. *Aerial Mapping: Methods and Applications*, Lewis Publishers, Boca Raton, Florida, 322 p.

Articles (or Chapters) in a Book:
Webb, H., 1991. Creation of digital terrain models using analytical photogrammetry and their use in civil engineering, *Terrain Modelling in Surveying and Civil Engineering* (G. Petrie and T.J.M. Kennie, editors), McGraw-Hill, Inc., New York, N.Y., pp. 73-84.

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).

9 **Acknowledgments:** In keeping with the process of blind reviews, authors are asked not to include acknowledgments in manuscripts submitted for peer review. An acknowledgment may reveal a considerable amount of information for reviewers that is not necessary or desirable for their evaluation of the manuscript. After a manuscript is accepted for publication, the lead author will be encouraged to insert appropriate acknowledgments.

Information on Manuscript Review Procedures: Corresponding authors of manuscripts submitted for review will receive an e-mail from the Editor acknowledging receipt of the manuscript. Details on *PE&RS* Manuscript Review Procedures can be found at http://www.asprs.org/pers/ReviewProcedure.

Manuscript Submission: All peer-reviewed manuscripts should be emailed to:

Dr. Russell G. Congalton, Editor-in-Chief
Photogrammetric Engineering & Remote Sensing
4 Ryan Way
Durham, NH 03824 USA
E-mail: russ.congalton@unh.edu; Tel.: (603) 862-4644

Special Issue Manuscript Submission: These instructions also apply to manuscripts submitted for a Special Issue. However, Special Issue manuscripts and Cover Letters should be sent directly to the Guest Editor, not to Dr. Congalton. Please refer to the Special Issue Call for Papers for the Guest Editor contact information.

NOTE: Authors should NOT MAIL MANUSCRIPTS TO ASPRS HEADQUARTERS. This will cause the review to be delayed.

***Instructions last updated January 2013*

ASPRS Certification Program

A clear level of standard in an unclear environment

http://www.asprs.org/Certification-Program/Introduction-to-ASPRS-Certification-Program.html