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Rochester Institute of Technology
Chester F. Carlson Center for Imaging Science
Digital Imaging and Remote Sensing Laboratory

Annual Report for the Academic Year 2011-2012

on the Activities of the

Digital Imaging and Remote Sensing Laboratory

Prepared by the DIRS Laboratory

David W. Messinger, Ph.D.
Laboratory Director

John R. Schott, Ph.D.
Frederick & Anna B. Wiedman Professor

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1 Introduction

As we look back on the 2011-2012 Academic Year in the Digital Imaging and Remote Sensing Lab, there are many great successes to celebrate as well as many exciting opportunities for future pursuit. As always, this success is the result of the dedication, hard work, and ingenuity of our faculty, staff, and most importantly, our students. DIRS continues to support over 40 students at the BS, MS, and Ph.D. levels, primarily in Imaging Science, but also across RIT. We are supporting MBA students in the Saunders College of Business, MS students in Computing and Information Science, BS and MS students in the School of Mathematical Sciences, as well as others. We continue to form strong collaborations across RIT, counting programs with faculty and students from the Kate Gleason College of Engineering, the Saunders College of Business, the College of Liberal Arts, the College of Applied Science and Technology, the Golisano College of Computer and Information Science, and the National Technical Institute for the Deaf among our portfolio of ongoing or proposed research projects.

In the past year we have achieved many milestones and demonstrated capabilities to impact real world problems across a range of applications and constituents. In the fall of 2011, we flew our WASP airborne sensor over flooded regions of New York State after both Hurricane Irene and Tropical Storm Lee. We also conducted a workshop with first responders for these events in collaboration with the Institute for the Application of Geospatial Technology at Cayuga Community College in Auburn, NY. Additionally, we held the Joint Workshop on Disaster Response as part of the Information Products Laboratory for Emergency Response, an NSF-funded program. This workshop featured invited speakers from the US Geological Survey, Cornell University, ImageCat, Inc., and Tomnod Inc., all significant parties in the global Disaster Response community. In the spring of 2011, a team lead by Dr. Jan van Aardt, and with participants from GCCIS, NTID, and COLA at RIT, as well as the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), submitted a major grant proposal to the NSF Integrated Graduate Education Research and Training (IGERT) program. This multi-year program, if awarded, will fund several Ph.D. students in Imaging Science and Computer and Information Science in research projects related to the technological approaches to, and the societal complexities associated with, disaster response and management.

The DIRSIG research and development team held four DIRSIG training classes both at RIT and across the country. DIRSIG has grown in use across the aerospace and civilian remote sensing communities. Among the major accomplishments this year related to simulation and modeling was the continued development of a high fidelity simulation of the Landsat Data Continuity Mission (to be Landsat 8 after launch). This simulation allows both the system engineers and the Landsat science community to understand the capabilities of the system and develop and validate data processing systems for the new system prior to launch in 2013. Looking forward, the DIRSIG team is now preparing the way for a complete re-write of the simulation: DIRSIG 5. Plans for a new architecture and new interface are well underway as part of an IR&D effort while external funds for this undertaking are being sought. We'll make sure to keep everyone up to date on the progress of this exciting next step in the development of DIRSIG.

In the past year, the faculty, staff, and students have continued their high rate of scholarly output. The lab has cumulatively published more than 50 publications in peer reviewed journals and conference proceedings. We cumulatively attended more than 10 international conferences. In particular, DIRS sent 23 people (4 faculty, 5 staff, and 14 students) to the SPIE Defense and Security Sensing meeting in the spring of 2012, presenting over 25 papers across several conferences at the meeting. Additionally, several of our students have been recognized for outstanding research efforts. Abdul Syed, an Imaging Science Ph.D. candidate, won Best Student Paper at the GEOBIA conference in Brazil while Jamie Albano, also an Imaging Science Ph.D. candidate, won the Best Student Paper at the Department of Energy Conference on Data Analysis. Of particular note, David Kelbe won a very prestigious NSF Graduate Research Fellowship that will support his Ph.D. research project for several years. Additionally, Dave also won the RIT Bruce R. James Distinguished Service Award for his community service efforts. Congratulations are definitely in order for all.

Looking forward, in the Fall of 2012 the DIRS lab is conducting a major experiment field campaign encompassing several imaging modalities and ground target experiments. One goal of the campaign is to make all the data available to the Remote Sensing community. We also welcome the arrival of 7 new US Air Force officers to campus, 4 of whom will be pursuing MS degrees and 3 will be working toward their Ph.D. This represents a continuation of our strong relationship with the Air Force, and one that we will seek to continue long into the future.

As always, we thank the RIT administration for their support of our efforts. In particular, we wish to thank Dr. Stefi Baum, the Director of the Center for Imaging Science, Dr. Sophia Maggelakis, the Dean of the College of Science, Dr. Ryne Raffaelle, the Vice President for Research, and Deborah Stendardi, the Vice President for Government and Community Relations. Additionally, we greatly appreciate the support of RIT Provost Dr. Jeremy Haefner and President Dr. Bill Destler. We hope to be able to continue to play our part in the growth of RIT through advancing the science and art of remote sensing across a wide array of application areas.

David W. Messinger

David W. Messinger, Ph.D.
Associate Research Professor
Director, Digital Imaging and Remote Sensing Laboratory
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

2 DIRS Laboratory Overview

The Digital Imaging and Remote Sensing (DIRS) Laboratory is a research group within the Chester F. Carlson Center for Imaging Science. Our work focuses on the development of hardware and software tools to facilitate the extraction of information from remotely sensed data of the earth and the education of students who will continue this work for academia, government agencies, and private industry.

The DIRS group is made up of faculty and research staff working with over 40 students ranging from High School interns, to RIT students from the Baccalaureate through Doctoral level. Most students are degree candidates in Imaging Science, but students from other departments, such as Engineering and Mathematics, are often part of the student population supporting our research initiatives.

2.1 Laboratory Personnel

2.1.1 Faculty

Dr. Jan van Aardt, Associate Professor,
Research Interests: Application of imaging spectroscopy and LIDAR for spectral-structural characterization of natural systems
Contact Information: `vanaardt@cis.rit.edu`; 585-475-4229

Dr. Emmett Ientilucci, Assistant Research Professor,
Research Interests: Multi- and hyperspectral algorithm development; physics-based signature detection in hyperspectral imagery; low-light level imaging systems
Contact Information: `ientilucci@cis.rit.edu`; 585-475-7778

Dr. John Kerekes, Associate Professor
Research Interests: Image processing and algorithm development; image chain modeling and parametric analysis
Contact Information: `kerekes@cis.rit.edu`; 585-475-6996

Dr. Bob Kremens, Associate Research Professor,
Research Interests: Remote sensing characterization of forest fires; in-situ measurement systems; fusion of in-situ and remote measurements
Contact Information: `kremens@cis.rit.edu`; 585-475-7286

Dr. David Messinger, Associate Research Professor, DIRS Laboratory Director
Research Interests: Multi- and hyperspectral algorithm development; advanced mathematical approaches to spectral image processing
Contact Information: `messinger@cis.rit.edu`; 585-475-4538

Dr. Harvey Rhody, Professor,
Research Interests: Image processing algorithms and systems; three-dimensional imaging
Contact Information: `rhody@cis.rit.edu`; 585-475-6215

Dr. Carl Salvaggio, Professor
Research Interests: Novel techniques and devices for optical property measurement; applied image processing and algorithm development; image simulation and modeling
Contact Information: `salvaggio@cis.rit.edu`; 585-475-6380

Dr. John Schott, Frederick and Anna B. Wiedman Professor
Research Interests: Hyperspectral data analysis and algorithm development; multi and hyperspectral instrument development; synthetic scene simulation and modeling

Contact Information: schott@cis.rit.edu; 585-475-5170

Dr. Tony Vodacek, Associate Professor
Research Interests: Environmental applications of remote sensing; forest fire detection and monitoring; active and passive sensing of water quality
Contact Information: vodacek@cis.rit.edu; 585-475-7816

2.1.2 Research & Support Staff

Dr. Scott Brown: brown@cis.rit.edu; 585-298-9505
Dr. Kerry-Anne Cawse-Nicholson: nicholson@cis.rit.edu; 585-475-5037
Mr. Chris DeAngelis: deangelis@cis.rit.edu; 585-475-4215
Mr. Jason Faulring: faulring@cis.rit.edu; 585-475-4432
Dr. Michael Gartley: gartley@cis.rit.edu; 585-475-7194
Dr. Aaron Gerace: gerace@cis.rit.edu;585-475-4388
Dr. Adam Goodenough: goodenough@cis.rit.edu
Mr. Bob Krzaczek: krz@cis.rit.edu; 585-475-7196
Mr. Don McKeown: mckeown@cis.rit.edu; 585-475-7192
Ms. Erin Ontiveros: ontiveros@cis.rit.edu; 585-475-4465
Ms. Nina Raqueño: nina@cis.rit.edu; 585-475-7676
Dr. Rolando Raqueño: rolando@cis.rit.edu; 585-475-6907
Mr. Michael Richardson: richardson@cis.rit.edu; 585-475-5294
Ms. Cindy Schultz: schultz@cis.rit.edu; 585-475-5508
Mr. Andy Scott: arspci@cis.rit.edu; 585-475-5508
Ms. Melanie Warren: mawpci@cis.rit.edu; 585-475-5508
Ms. Amanda Zeluff: amzpci@cis.rit.edu; 585-475-6781

2.1.3 Student Researchers

Students pursuing research in the DIRS laboratory as of June 30, 2011:

BS (12)

Edward Amsden	Luca Ashok	Colin Axel
Tim Garvin	AnneMarie Giannandrea	Michal Kucer
Jonathan Lueders	Jessica Maben	Michael Rodgers
Kyle Ryan	Phil Salvaggio	Linnea Tullson

MS (8)

Javier Concha	Bo Ding	Michael Harris	James Letendre
Josh Zollweg	Jie Zhang	Ming Zhang	Tingfang Zhang

Figure 2.1-1: USAF and Canadian Forces students in the Imaging Science graduate program.

Ph.D. (26)

Jamie Albano	Bikash Basnet	Madhurima Bandyopadhyay	Kelly Canham
Bin Chen	Jake Clements	Monica Cook	Shea Hagstrom
Jared Herweg (USAF)	David Kelbe	Sanjit Maitra	Troy McKay
Lingfei Meng	Ryan Mercovich	David Nilosek	Nima Pahlevan
Sarah Paul	Paul Romanczyk	Shagan Sah	Katie Salvaggio
Jiangqin Sun	Shaohui Sun	Weihua Sun	William Wu
Jiashu Zhang	Amanda Ziemann		

2.2 Theses Defended in Past Year

- Joshua Zollweg, MS

Figure 2.1-2: DIRS students in Fall 2011.

- Jake Clements, Ph.D.
- Jared Herweg, Ph.D.
- Ryan Mercovich, Ph.D.
- Nima Pahlaven, Ph.D.
- Sarah Paul, Ph.D.
- Alvin Spivey, Ph.D.
- William Wu, Ph.D.

3 Research Project Summaries

3.1 Landsat Data Continuity Mission System Modeling with DIRSIG

Sponsor: NASA - Goddard Space Flight Center

Principal Investigator(s): Dr. John Schott

Research Team: Dr. Aaron Gerace, Dr. Michael Gartley, Dr. Scott Brown

Project Description:
This project provides support to the Landsat Data Continuity Mission (LDCM) with an emphasis on modeling radiometric and image quality issues associated with the Thermal Infrared Sensor (TIRS) and Operational Land Imager (OLI), 2 new sensors to be flown on the next Landsat satellite. Year one of this work focused on developing the DIRSIG capabilities necessary to model the geometric properties of OLI and TIRS while year two efforts focused on using the model to identify image quality issues associated with the sensors. With the launch of Landsat 8 scheduled for early 2013, current modeling efforts are being used to make decisions regarding on-orbit calibration while future modeling efforts will be used to support the LDCM team to help understand on-orbit phenomenology.

Project Status:
The studies conducted in year 3 of this project focused on potential methods that could be used to calibrate the TIRS and OLI instruments. These studies included:

Modeling sources of non-uniformities in DIRSIG The DIRSIG tool was enhanced to enable the modeling of non-uniformities on a detector-to-detector level. For this study, the NASA and USGS LDCM team provided measurements of gain, bias, nonlinearity, noise, and quantization for each detector of the OLI sensor. These measurements were provided as input to DIRSIG to develop an OLI sensor model. The sensor model was then used to image the simulated Lake Tahoe landscape to generate raw data as seen in Figure 3.1-3 (left). Figure 3.1-3 (center) shows the data after a gain and bias correction is applied to the raw data. Finally, Figure 3.1-3 (right) shows a stretch of the data shown in Figure 1 (center) to illustrate the potential need for further correction.

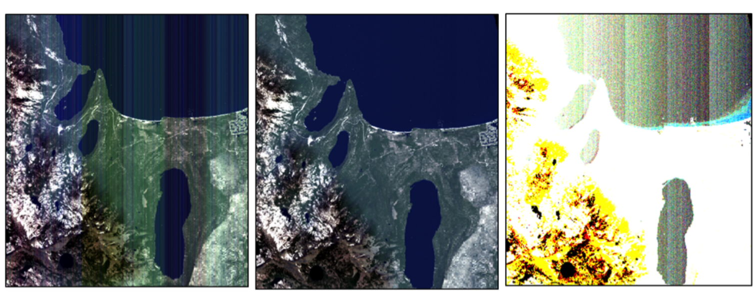


Figure 3.1-3: (Left) DIRSIG rendering of Lake Tahoe, California with all OLI non-uniformity effects applied. (Middle) Gain- and Bias-corrected data using nominal measurements. (Right) stretched data.

In a more quantitative analysis, the OLI sensor model used in the above study was applied to a uniform scene that was developed specifically to determine if the OLI instrument would meet its on-orbit pixel-to-pixel uniformity requirement. The results of this work concluded that OLI would in fact meet its uniformity requirement assuming on-orbit non-uniformities don't vary significantly from ground-based measurements.

Utilizing a side-slither (90 degree yaw) maneuver to flat field OLI and TIRS. The LDCM calibration team decided that a side slither maneuver would be appropriate on-orbit due to concerns of potential non-linear radiometric responses in the OLI detectors. To support this effort, RIT modeled the side slither maneuver using the DIRSIG tool to identify potential invariant sites around the world that would be suitable to support such a maneuver. Figure 3.1-4 illustrates data that is collected in normal imaging mode versus data collected in side slither mode. The data collected from performing a 90 yaw can be used to determine the relative gains of each detector in an effort to flat-field the data.

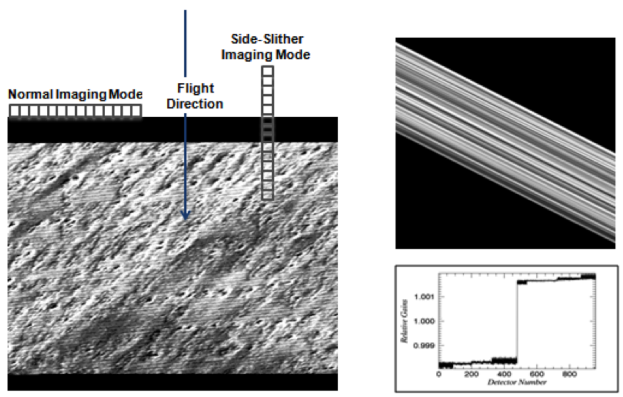


Figure 3.1-4: Demonstration of the Side Slither approach.

To support the on-orbit side slither maneuvers, the DIRSIG simulated maneuvers were performed over several worldwide pseudo-invariant calibration sites and the relative gain variability calculated for each site. Figure 3.1-5 shows the gain variability that was calculated from each of the simulated maneuvers. These results indicate that several sites around the world will be appropriate to support side slither calibration. This information is being used by the LDCM calibration team to schedule on-orbit maneuvers during the first 30 days after launch.

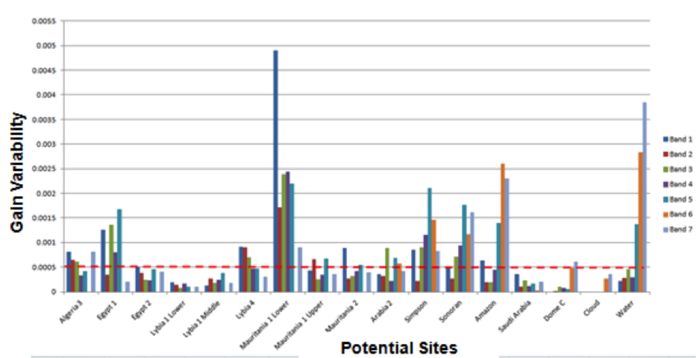


Figure 3.1-5: Side slither site ananlysis.

Cross-registration of OLI and TIRS data The DIRSIG sensor model was enhanced to allow the implementation of sensor offsets on the virtual satellite. This capability was used in this year's effort to develop a method to cross-register the TIRS and OLI data. This can be used to attempt to isentify features that are highly correlated between to assess the expected levels of registration.

3.2 NASA Land Surface Temperature Product

Sponsor: NASA, JPL, NASA Goddard, USGS EROS

Principal Investigator(s): Dr. John Schott

Research Team: Monica Cook (CIS - Ph.D.)

Project Description:
Land Surface Temperature (LST) is an important Earth System Data Record for many applications and areas of research, including environmental models, numerical weather prediction, and climatic variability. The goal of this work is to develop a LST product for the Landsat archives from Landsat-4 to the currently operating Landsat-5 and Landsat-7. The spatial and temporal resolution of the Landsat series, as well as the historical and projected future coverage, makes it an optimal satellite series for a product of this nature. The single thermal band of the Landsat satellites is largely under-utilized because both the emissivity and a characterization of the atmospheric profile are necessary in order to extract the temperature. A newly available high resolution, seasonal emissivity database derived from ASTER data will be combined with atmospheric characterizations produced using radiative transfer codes to compute the LST for this product.

With the necessary atmospheric characterization (pressure, temperature, and water vapor content), a radiative transfer code (MODTRAN) can be used to generate the atmospheric parameters (upwelled radiance, downwelled radiance, and transmission) required to compute the LST. This is the main focus of this research. The North American Regional Reanalysis (NARR) program provides this atmospheric profile data for North America covering the spatial and temporal range of the Landsat series. To calculate the LST for each pixel, this data needs to be input into the radiative transfer code and interpolated both spatially and temporally to match the resolution of the Landsat scenes.

Project Status:
This is a joint project with NASA JPL which will focus on the emissivity component with RIT focused on the atmospheric compensation. A process has been implemented that integrates the NARR data with the Landsat scene to interpolate the necessary information to generate parameters for every pixel in the Landsat scene. Because of the volume of data, number of MODTRAN runs required, and number of Landsat scenes, computing time and resources had to be considered in order to optimize the process. Sensitivity studies to analyze interpolation techniques as well as processing implementation were performed.

Current work is focused on processing large batches of scenes in order to validate this initial process. Initial results have been validated using both ground truth from buoys and lake platforms and JPL's temperature retrieval process over water where the emissivity is known. As shown in Figure 3.2-6, the average error between the RIT and JPL retrieved temperatures in the Salton Sea was 0.286 K and the average error between the RIT retrieved temperature and the ground truth platform temperature was 0.739 K as shown in Figure 3.2-7. Similarly for Lake Tahoe as shown in Figures 3.2-8 and 3.2-9, average errors were 0.265 K and 0.797 K for the JPL and ground truth buoy temperatures respectively.

Future work includes developing confidence metrics or error analysis to accompany temperature predictions. These will be developed using results with known ground truth based on atmospheric data used in the process such as humidity and temperature values. Future work also includes extending this process for global coverage.

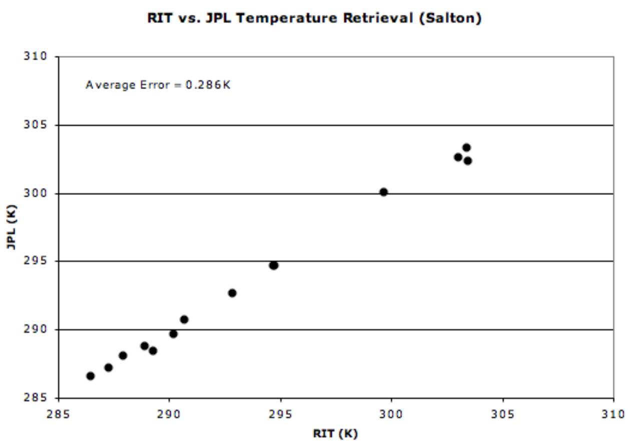


Figure 3.2-6: Comparison of RIT and JPL retrieved temperatures over the Salton Sea.

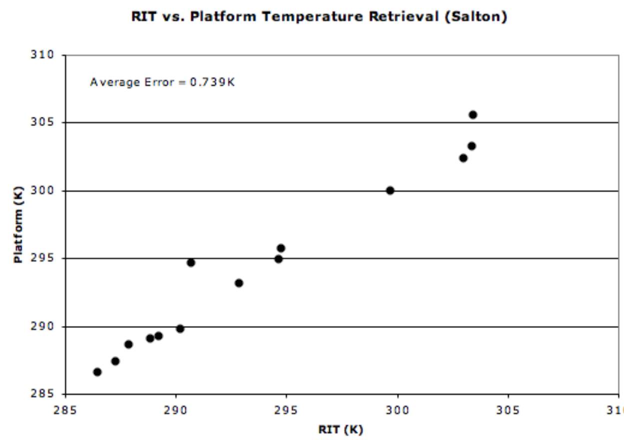


Figure 3.2-7: Comparison of RIT retrieved temperatures and ground truth platform temperatures from the Salton Sea.

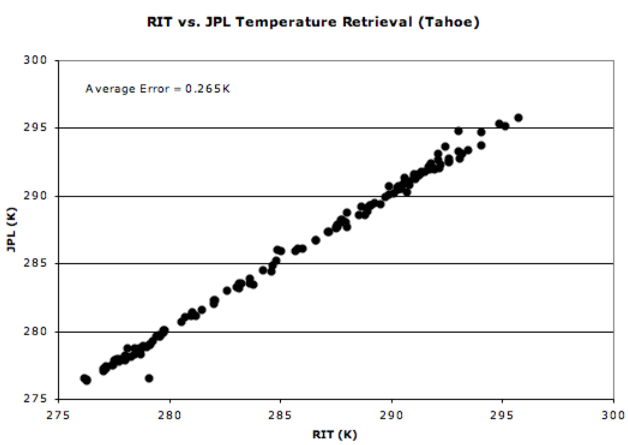


Figure 3.2-8: Comparison of RIT and JPL retrieved temperatures over Lake Tahoe.

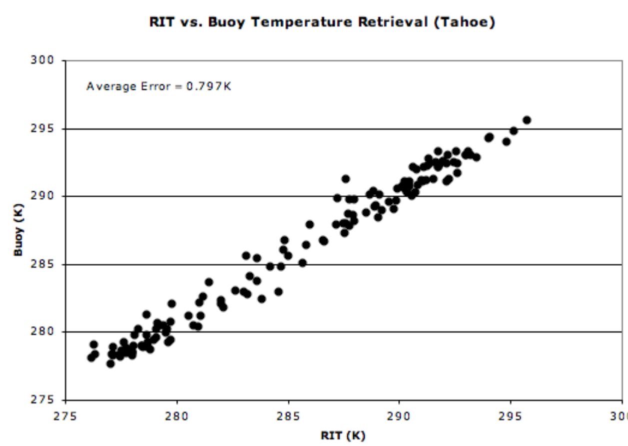


Figure 3.2-9: Comparison of RIT retrieved temperatures and ground truth buoy temperatures from Lake Tahoe.

3.3 Landsat 5 & 7 Thermal Calibration

Sponsor: NASA & US Geological Survey

Principal Investigator(s): Dr. John Schott

Research Team: Nina Raqueño

Project Description:
RIT continues to monitor the current calibration of both Landsat 5 & 7 thermal bands with surface corrected temperatures from NOAA buoys.

Landsat 7 Thermal Calibration Results
Ground truth surface water temperatures ranging between 4 to 25 degrees Celsius were collected on Lake Ontario and Lake Erie between the months of March and September, 2011. The analysis of the 2011 data was further supplemented with buoy corrected temperatures that were converted to surface-leaving radiances and extrapolated to space using MODTRAN. The results are presented by plotting the image derived radiance and the ground truth radiance for 20 individual samples (Figure 3.3-10). The 2011 data indicate an average bias error of -0.018 [w/m^2 sr μm] which is equivalent to a temperature bias of -0.14 K. This data indicates that the Landsat ETM+ thermal band 6 is still operating nominally over typical temperatures encountered on the earth's surface.

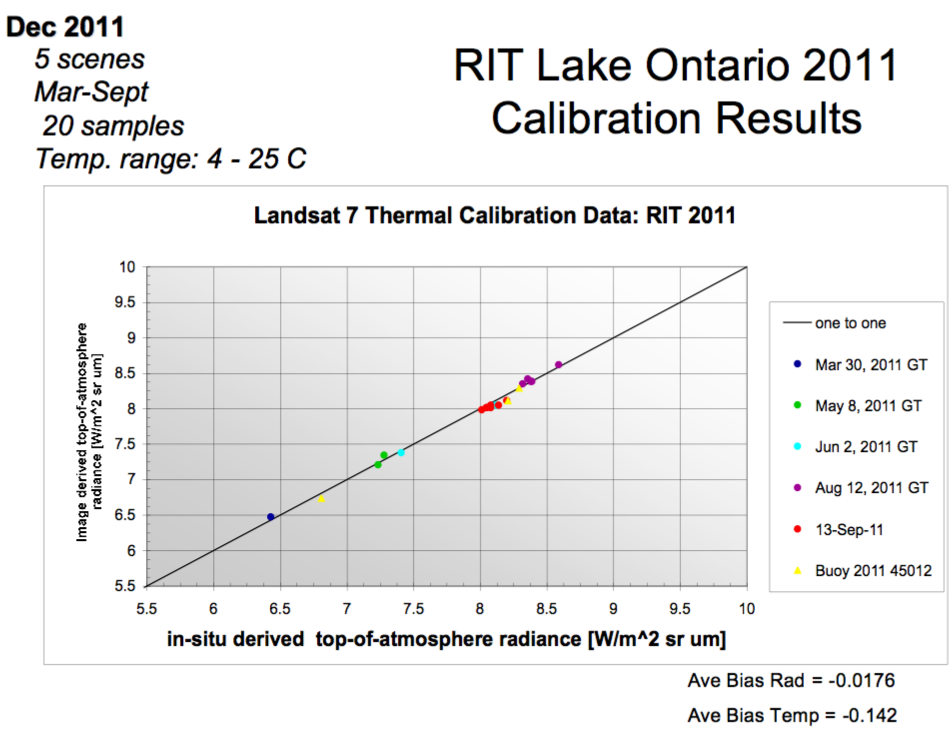


Figure 3.3-10: Plot of predicted versus observed at sensor radiance for Landsat ETM+ data collected during the 2011 season.

During 2012 calibration efforts focused on utilizing the NOAA buoy data to create a automatic calibration workflow. Figure 3.3-11 presents RIT's thermal calibration results from the Spring 2012 featuring results from just two of the potential ˜100 buoys.

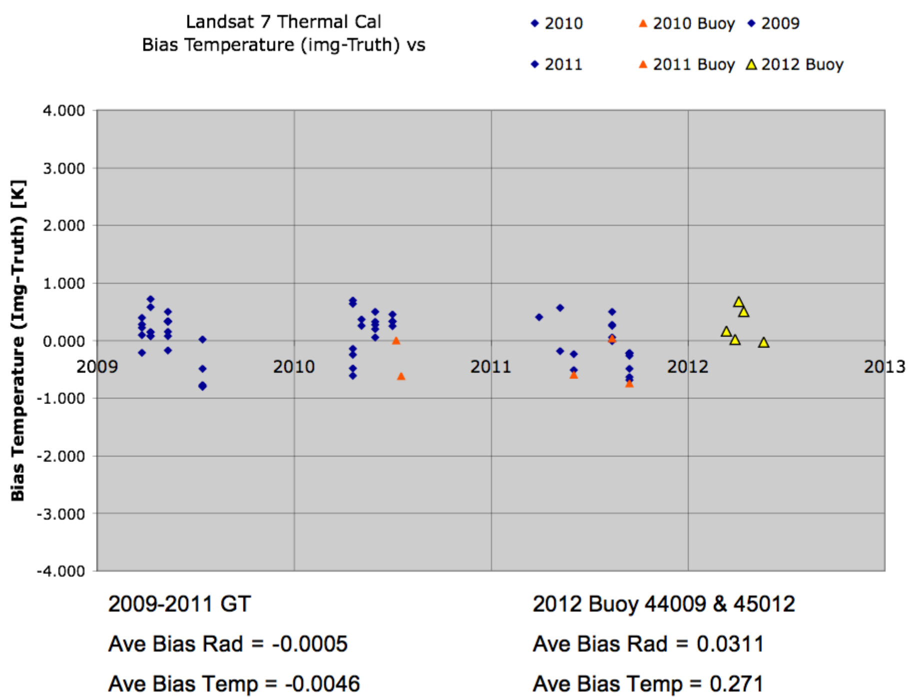


Figure 3.3-11: Thermal calibration results in terms of bias temperature for 2009-2012(spring)

Landsat 5 Thermal Calibration Results
During 2011, surface water and buoy temperatures ranging between 4 to 26 degrees Celsius were compared to Landsat predicted temperatures. The results are presented by plotting the image derived radiance and the ground truth radiance for 20 individual samples (Figure 3.3-12). A regression line is then fitted to the data and compared to the ideal calibration one to one line. In November 2011 Landsat 5 ceased operations therefore no results are show for 2012. The research focus shifted to analyzing new buoy stations and automation.

Project Status:
RIT continues to monitor the thermal accuracy of both of the active Landsat instruments (5 & 7). The results generated from Great Lakes ground truth and the NOAA buoy methodology are presented to NASA's Landsat Calibration Team twice annually.

With the anticipation of the launch of LDCM (Landsat8) RIT is converting the manual buoy calibration process into an automated workflow.

3.4 Small Target Radiometry Restoration

Small Target Radiometry Restoration

Sponsor: United States Department of Energy

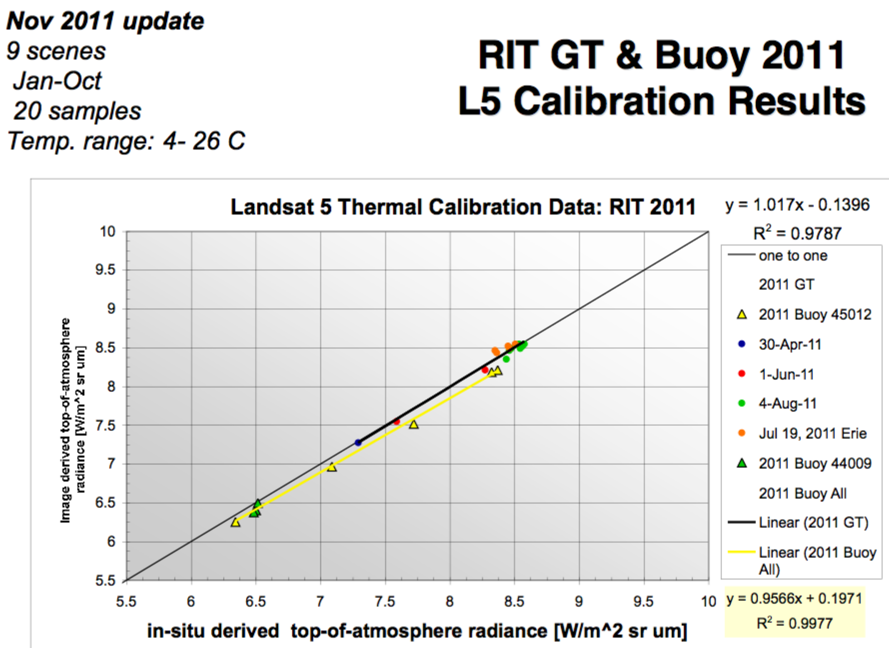


Figure 3.3-12: 2010 Landsat 5 TM thermal calibration results of satellite predicted radiances compared to truth.

Principal Investigator: Carl Salvaggio

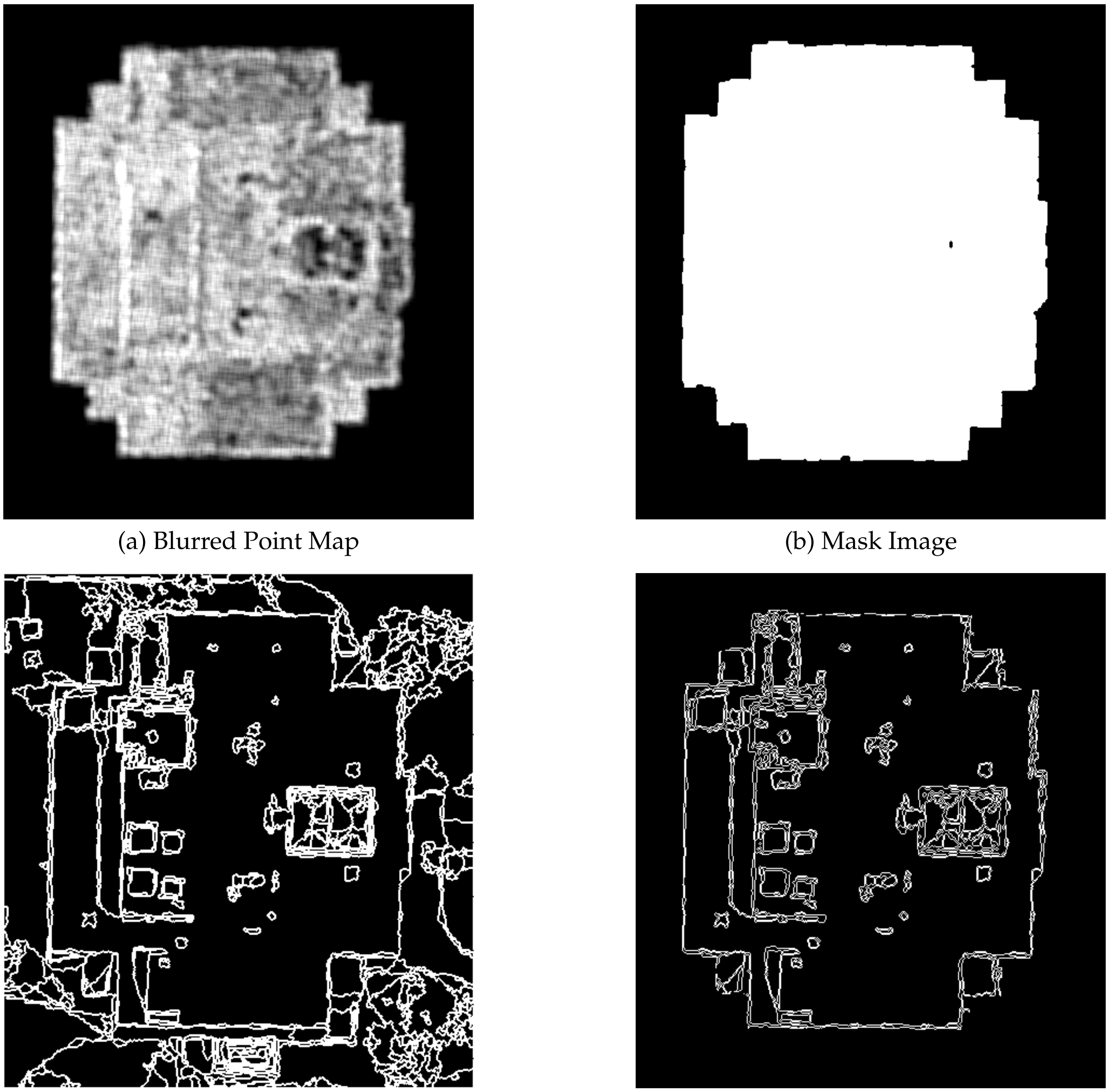
Research Team: Shaohui Sun (Graduate Student), Sarah Paul (Graduate Student), David Nilosek (Graduate Student)

Project Description:
A critical component of our approach to small target radiometric restoration is the use of DIRSIG to predict the radiance under a variety of different imaging scenarios involving variant target and background material optical properties, target positioning, and thermal distribution on the target surfaces. As part of this, accurate geometric representations of the targets and background of interest are required. The following describes our continued improvement of our methodologies in this area that were accomplished over the past year, specifically applied to rooftop boundary extraction.

Roof Outline Detection and Description:
A method was developed to extract roof information from both LiDAR data and aerial imagery. LiDAR is utilized to detect rooftops and help generate rough roof outlines. A segmentation method is applied to the imagery to form an information rich edge map for the purpose of refining these outlines. A simple and fast correlation based registration method is also adopted in this research to fuse LiDAR and imagery. Fig. 3.4-13 shows the workflow in which the roof edge map is extracted from the complete edge map by applying a binary roof mask image, and Fig. 3.4-14 shows the generation of the approximated outline and the outline refinement process.

Large Scale Urban Modeling:

We further developed a method which is fully automatic for 3D building detection and modeling by processing airborne LiDAR point clouds. The building footprints and the terrain are first separated from vegetative areas by applying a graph cuts optimization technique based on the distribution of point normals. When only rooftops and the terrain are left in the scene, a novel hierarchical Euclidean clustering method has been developed to extract rooftop patches and the terrain. For each rooftop patch, a region growing based segmentation method has been presented that detects all significant features on the rooftop. Boundary points are generated under some reasonable assumptions for typical rooftop structures. Finally, a 2.5D dual-contouring method is adopted for modeling process. The models utilize a UTM coordinate system and are ready to be embedded in to any GIS application. Fig. 3.4-15 shows the reconstruction results for portions of the data collector over the campus of the Rochester Institute of Technology and the city of Rochester. The terrain, in which there is some elevation variation, is also modeled.



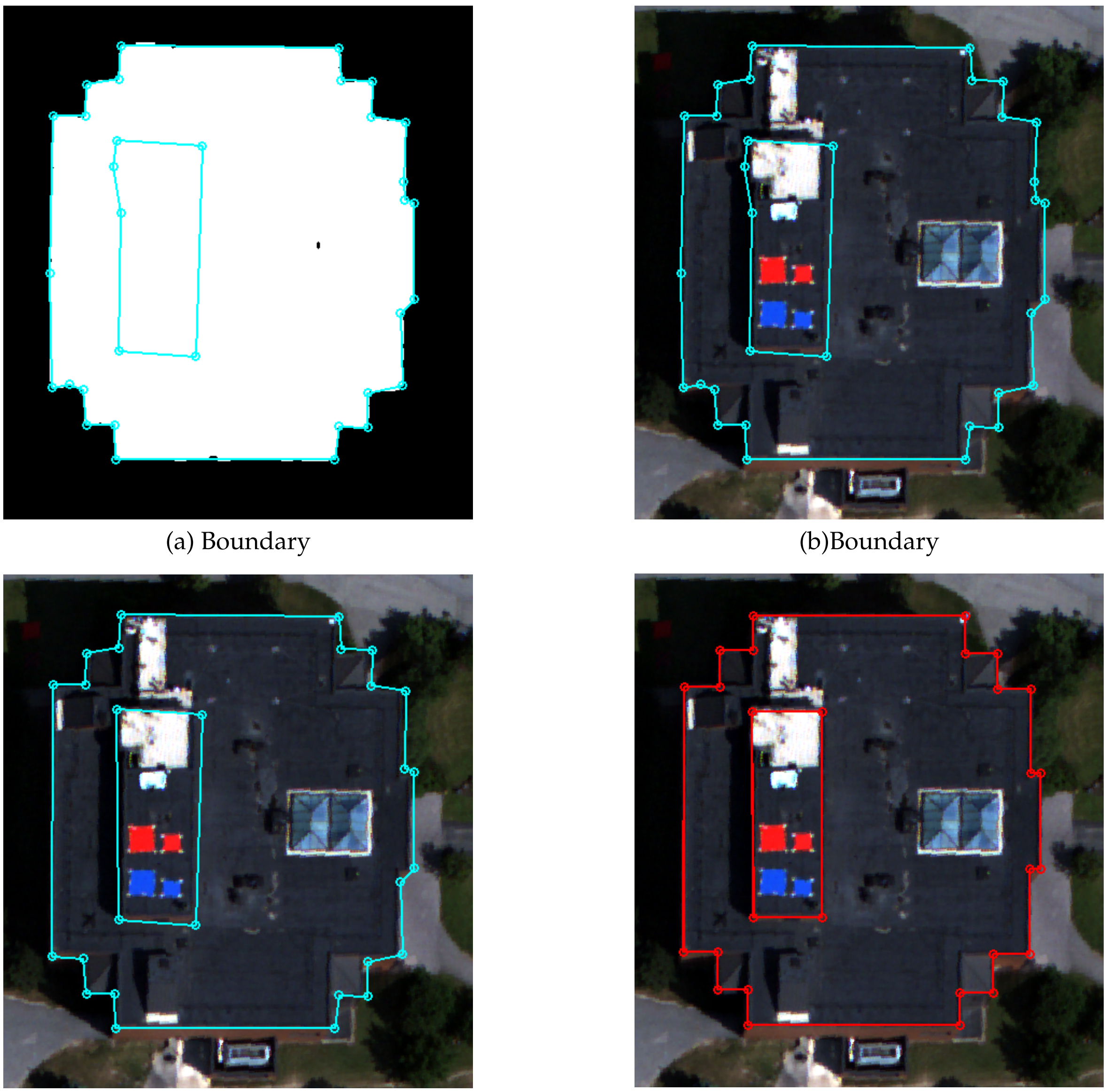
(a) Blurred Point Map

(b) Mask Image

(c) Edge Map

(d) Roof Edges

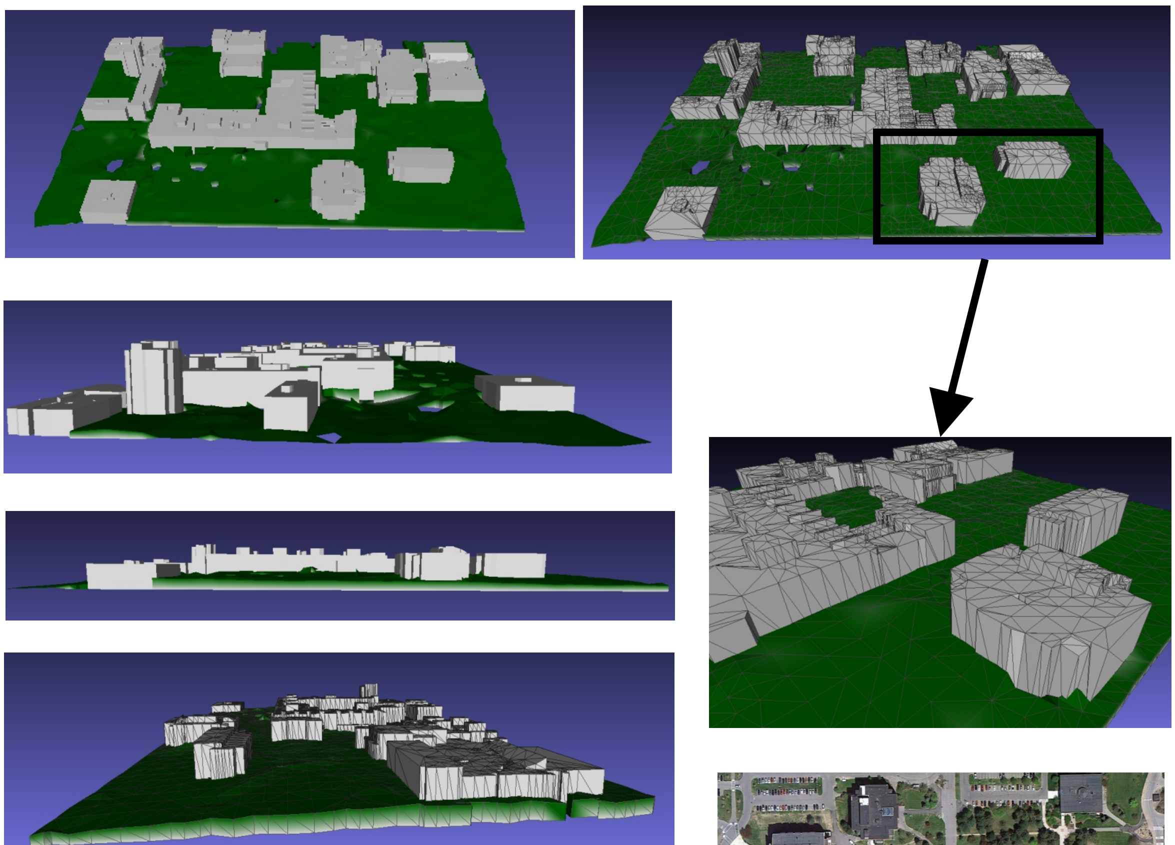
Figure 3.4-13: Workflow utilized to isolate the roof and roof feature edge map from those edges derived from the original grey-scale image data.



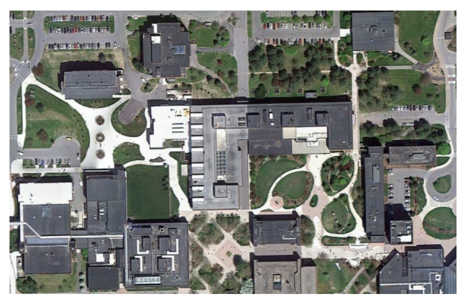
(a) Boundary (b)Boundary

(c) Vertices Removal (d) Refined Boundary

Figure 3.4-14: Illustration of the workflow used to obtain the final refined roof top boundary.

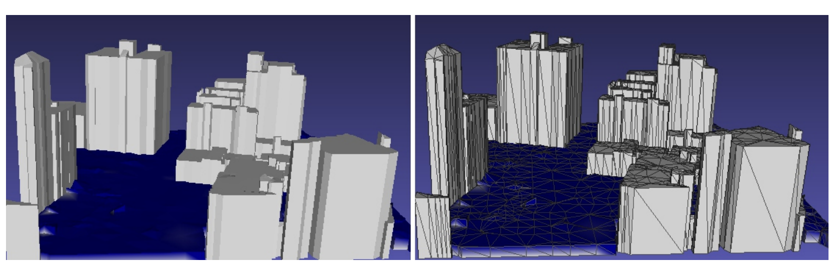


(a) - 2: Reconstruction of example 1



(a) - 1: Optical aerial ortho-photo example 1
(courtesy of Google Map)

(b) - 1:Optical aerial ortho-photo example 2
(courtesy of Google Map)



(b) - 2: Reconstruction of example 2

Figure 3.4-15: Reconstruction of the buildings in the Greater Rochester area (terrain included).

3.5 Analysis of Heavily Laden Vehicles

Sponsor: United States Department of Energy

Principal Investigator: Carl Salvaggio

Research Team: Troy McKay (Graduate Student), Jason Faulring

Project Description:
The ultimate goal of our research is to design a system of passive ground-based sensors that can accurately measure the weight of large over-the-road vehicles. To do this we identified multiple signatures that were likely to correlate to vehicle weight and could also be measured remotely from passive ground-based sensors. We have designed and executed several experiments and full scale field tests to quantify the correlation of each signature to vehicle weight during optimized collection conditions. The results of these experiments and field tests are have been used to discard signatures with low correlation to vehicle weight leaving only the strongest signatures. A final full scale field test is currently being planned that will simultaneously measure all of the proven signatures. We will analyze the results of the final full scale field test and statistically determine the best way to combine the data from the individual signatures into a single weight measurement with better accuracy than any of the signatures could provide alone.

Tire Deflection:
One promising signature that correlates strongly with vehicle weight is tire footprint. The tire footprint is the total amount of the tires surface area that is in contact with the roadway. As the vehicle load increases the tire footprint also increases. To precisely measure the tire footprint of a moving vehicle, we have utilized a stationary LiDAR system that exploits the movement of the vehicle to create a high resolution 3D map of the tire as it passes the sensor. This LiDAR data can be used to accurately calculate the total tire footprint for each of the vehicle's tires, and the footprint data can be used to estimate the vehicle's weight. Fig. 3.5-16 shows an example of a LiDAR point cloud collected for the rear wheel of the test vehicle.

Frame Twist:
Another promising signature we are currently analyzing is the amount of frame twisting that occurs during acceleration. When a vehicle accelerates from a stop, the torque generated by the engine is transferred to the drive wheels through the drive shaft. This transfer of energy causes the frame of the vehicle to twist. This frame twisting will be greater for a heavily laden vehicle than for an unladen vehicle when accelerating at the same rate. We have measured this frame twisting signature by monitoring the frame during acceleration from a stop using high definition video. The high definition video was then processed to measure the amount of frame twisting occurring in each frame. The frame twisting data is combined with the acceleration rate of the vehicle to estimate the vehicle's weight. Fig. 3.5-17 shows a high definition video frame with the bumper being tracked to measure the amount of frame twist occuring.

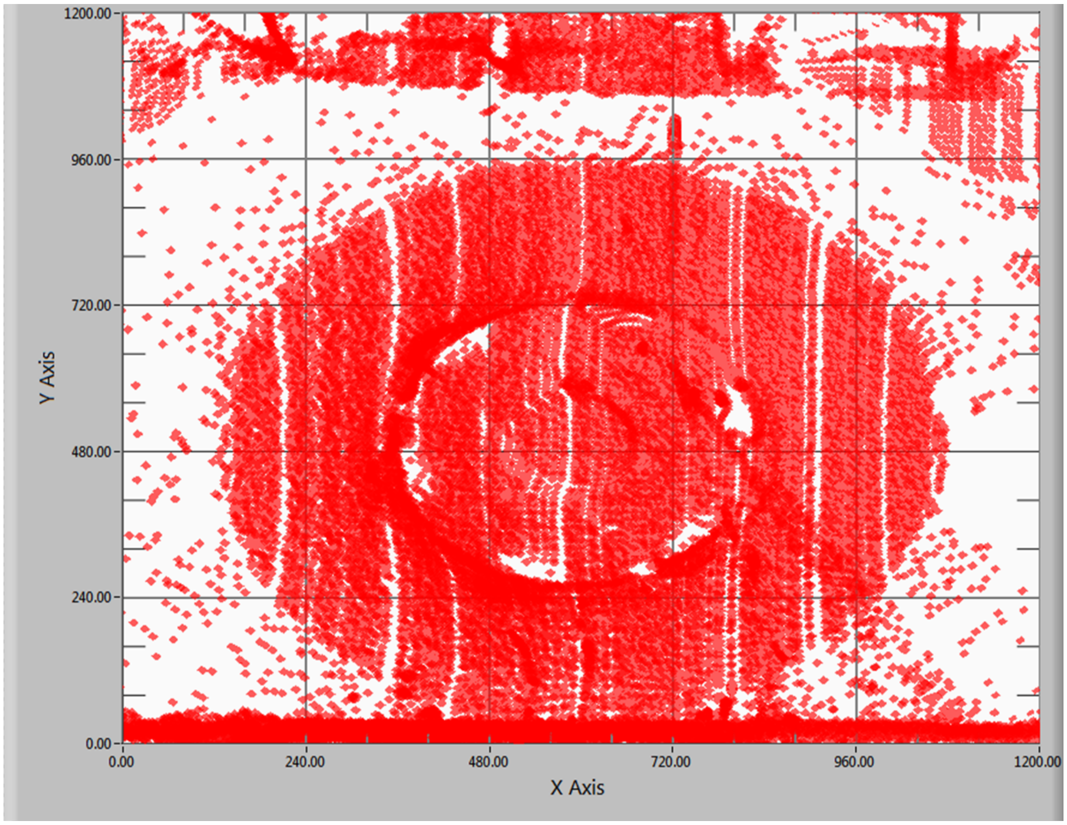


Figure 3.5-16: LiDAR point cloud of the rear wheel of the test vehicle.

Figure 3.5-17: High definition video frame with the angle of the bumper being tracked to measure frame twist.

3.6 Accurate Radiometric Temperature Measurements using Thermal Infrared Imagery of Small Targets, Physics-Based Modeling, and Companion High-Resolution Optical Image Data Sets

Three-Dimensional Geometry Extraction from High Frame Rate Oblique Imagery

Sponsor: ITT Exelis

Principal Investigator: Carl Salvaggio

Research Team: Katie Salvaggio (Graduate Student)

Project Description:
The focus of this research is to use photogrammetric and computer vision techniques in order to extract 3D scene geometry from remotely sensed oblique imagery collected at a high frame rate as compared to nadir imagery. We have previously had success generating models from nadir looking imagery collected with the RIT WASP sensor. However models derived from nadir looking imagery are somewhat lacking due to the fact that the sensor is looking straight down, and details such as the sides of buildings cannot be reconstructed simply because they do not appear in the imagery. When looking from an oblique angle, the building sides come into view and therefore can be reconstructed and included as part of the model.

The Data Set:
The image data set that we have been using was collected by the ITT Exelis sensor, WAAS (Wide Area Airborne Surveillance), over the downtown Rochester area. The platform was flown in a circular pattern around the central part of the city with the turret fixed on a single location. Image frames 4872×3248 pixels were collected at a rate of 2 frames per second using a single visible band. The system itself has 5 visible frame cameras, positioned such that they can be used to make a mosaic encompassing a larger view than just a single frame, in addition to 4 infrared cameras. At the present time, we have only been using data from a single visible camera.

3D Reconstruction Workflow:
In general, there are three steps in the pipeline that leads to automated 3D reconstruction: (1) a feature detection and matching algorithm is utilized to provide image to image correspondences, (2) Structure from Motion (SfM) algorithms are then used to estimate the pose using the correspondences, and (3) Multi-View Stereo (MVS) algorithms use the pose estimation and images to produce dense 3D reconstructions. Currently, we are using a GPU implementation of the Scale-Invariant Feature Transform (SIFT), originally developed by David Lowe, to perform the initial feature detection and matching. Initial matches are then pruned to eliminate erroneous matches and the pruned set of matches is then used as input to a SfM algorithm. We have been using Bundler, a bundle adjustment package developed by Noah Snavely, to estimate the pose of the cameras. An example of a point cloud output from Bundler with camera positions included is shown in Figure 3.6-18. The estimates of the cameras are then used as input to a Patch-based Multiview-Stereo (PMVS) algorithm, developed by Yasutaka Furukawa, in order to obtain a dense model of the scene. In this case the output is a point cloud, or set of vertices in a three-dimensional coordinate system; an example view of the point cloud is shown in Figure 3.6-19 with a reference image to the Rochester, NY skyline. Finally, the point cloud can be rendered so as to develop a 3-dimensional surface, known as a mesh, that is generally preferred for its ease of viewing. An example of the entire scene rendered into a mesh is shown in Figure 3.6-19. At the present time, the point cloud is not referenced to a world coordinate system and therefore is not tied to a specific location on the earth and is related to a real world scale by some arbitrary scale factor. We are currently working on developing methods that would result in geo-accurate point clouds and have had some success with nadir looking imagery, however there are additional problems that must

be dealt with in relation to oblique imagery.

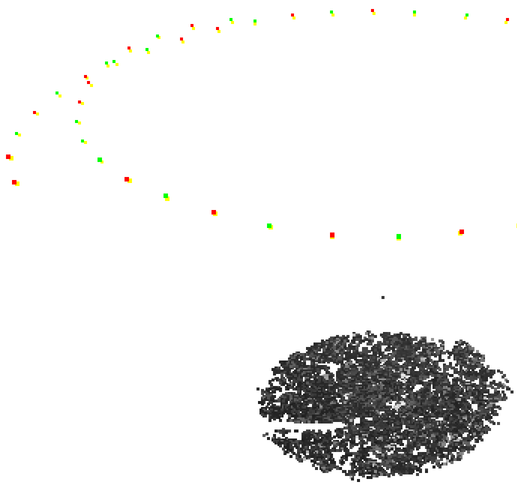


Figure 3.6-18: Camera frame positions, as derived using Bundler, shown by the red and green points above the ground plane.

(a) Rochester, NY skyline.

(b) 3D Reconstruction of the Rochester, NY skyline.

Figure 3.6-19: Visual comparison of an image of the Rochester, NY skyline and the 3D model from the same view. The 3D model was generated from WAAS imagery using the 3D workflow. Image (a) from http://linkagesrochester.org/drupal/node/29.

3.7 Rx-Cadre Experiments

Sponsor: USDA Forest Service, Northern Research Station

Principal Investigator(s): Dr. Robert Kremens

Project Description:
The availability of integrated, quality-assured, fuels, fire, and atmospheric data for development and evaluation of fuels, fire behavior, smoke, and fire effects models is limited. The lack of co-located, multi-scale measures of pre-fire fuels, active fire processes, and post-fire effects hinders our ability to tackle fundamental fire science questions. The lack of such datasets became clear following discussions within the Core Fire

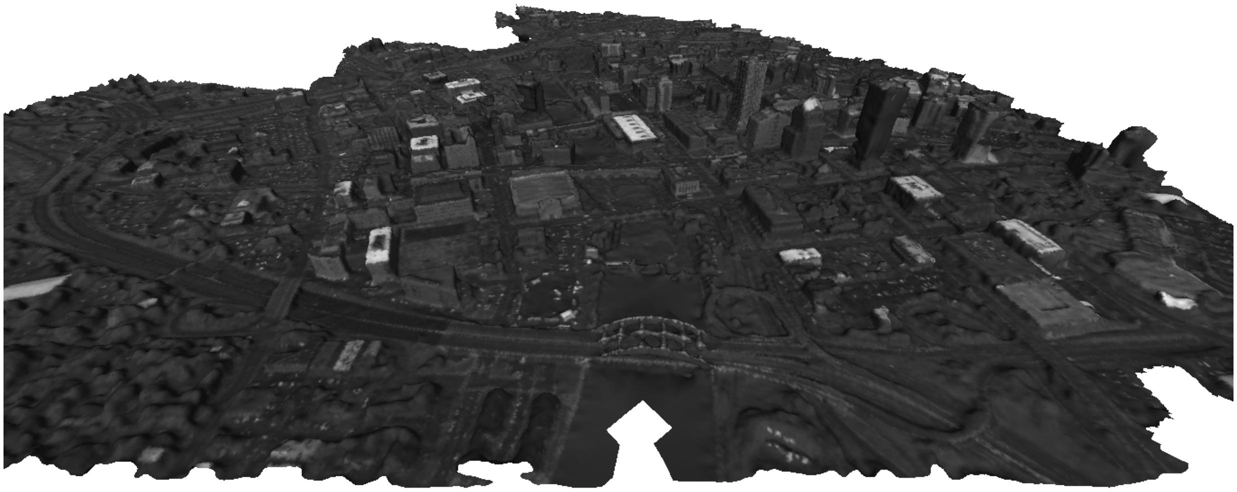


Figure 3.6-20: 3D Point cloud obtained from WAAS imagery has been converted into a triangular mesh using Poisson surface reconstruction in Meshlab (free software).

Science Caucus, a group of 30 scientists that meet periodically to discuss fire behavior research, identify knowledge gaps, and outline a strategic direction for continued research. Consequently, the Caucus pooled their own operational and in-kind resources and collaboratively instrumented and collected fire and fuels data on prescribed fires in the southeastern United States in a research effort called the Prescribed Fire Combustion and Atmospheric Dynamics Research Experiment (RxCADRE). RxCADRE enabled scientists to develop processes for collecting complementary research data across fire-related disciplines before, during, and after the active burning periods of prescribed fires with the goal of developing synergies between fuels, fuel consumption, fire behavior, smoke management, and fire effects measurements for fire model development and evaluation. RIT has been an integral part of both the Core Fire Science discussions and the RxCADRE experiment campaign since these talks and experiments began in 2007.

In 2008, 15 RxCADRE scientists (including PI Robert Kremens) demonstrated the capacity for making collaborative measurements by characterizing fire-atmospheric dynamics on 5 prescribed fires in several southern pine fuelbed types (longleaf pine/grass, longleaf pine/saw palmetto, and longleaf pine sandhills) at Elgin Air Force Base, FL and the Joseph W. Jones Ecological Research Center, GA. The RxCADRE teams collected data on pre-burn fuel loads, fuel consumption, fuel moisture, ambient weather, in situ convective dynamics, plume dynamics, radiant heat release, in situ fire behavior, and selected fire effects. This effort created linkages between data generation and data use for fire and fire effects model development and evaluation, and provided important practical experience deploying diverse arrays of field measurement devices. Data and results from the 2008 experiments were presented at the 4th International Fire Ecology and Management Congress in December, 2009. Lessons learned were documented and incorporated into 2010 and 2011 RxCADRE experiments (Kremens et al. 2012; Kremens et al. 2010). In 2011, RxCADRE monitored 3 prescribed fires in fuelbed types composed of longleaf pine, grass, turkey oak, and saw palmetto, refining logistics and sampling protocols as a collaborative and integrated research team. Twenty additional scientists from NOAA, NASA, EPA, and SERDP also participated, providing prospects for diversifying expertise and funding sources in future years. Relevant grants, one-time discretionary funds, and in-kind support from RxCADRE participants for the 2008 and 2011 research campaigns were estimated at $2.5 million. RIT has participated in these experiments both in the collection and analysis of time-resolved airborne infrared data using the WASP instrument and in the design, construction and deployment of ground based sensors to measure infrared flux density, convective flow and combustion gas concentrations.

Project Status:
2011 marked the end of internally funded RxCADRE and new support for the campaign through the multi-agency Joint Fire Science program. The effort in 2012 will be more coordinated and robust and will target the critical data needs for evaluation and further development of fire and smoke models/tools such WFDS, FIRETEC, FOFEM, Consume, BlueSky, Daysmoke, and others. Participants from the Southern, Rocky Mountain, Pacific Northwest, Pacific Southwest, and Northern Research Stations, San Jose State University, University of Montana, Rochester Institute of Technology, and other research entities with operational support from the Department of Defense (DoD), and the Remote Sensing Applications Center (RSAC), offer a wide range of fuel, fire behavior, meteorology, smoke, and fire behavior monitoring expertise and equipment to instrument a minimum of six additional prescribed fires in grasslands and pine woodlands in the southeastern U.S. ranging in size from 50 to 1,000 hectares. These burns will leverage data and expertise derived from the seven burns already instrumented by RxCADRE. Specifically, we propose to: 1) quantify fuel characteristics and consumption across scales using standard methods, and with aerial and ground-based LiDAR, 2) measure fire-atmosphere interactions, plume dynamics, and ambient meteorological conditions, 3) measure surface fire behavior, 4) approach closure of the fire heat budget from measurements and estimates of total and effective heat of combustion and radiative, convective, latent, and soil heat dissipation, 5) characterize smoke emissions at the source and downwind from the fire, and 6) characterize first order fire effects (Fig. 3.7-21). RIT will develop ground station instruments for this project and will also fly WASP in support of the large fires (1000ha) observations. A schematic of the ground instrument packages (we will deploy 10 packages on each fire experiment) is shown in Figure 3.7-22. Similar packages were deployed on the RxCADRE experiments of 2011. Infrared flux density data from one of the RxCADRE fires is shown in Figure 3.7-23.

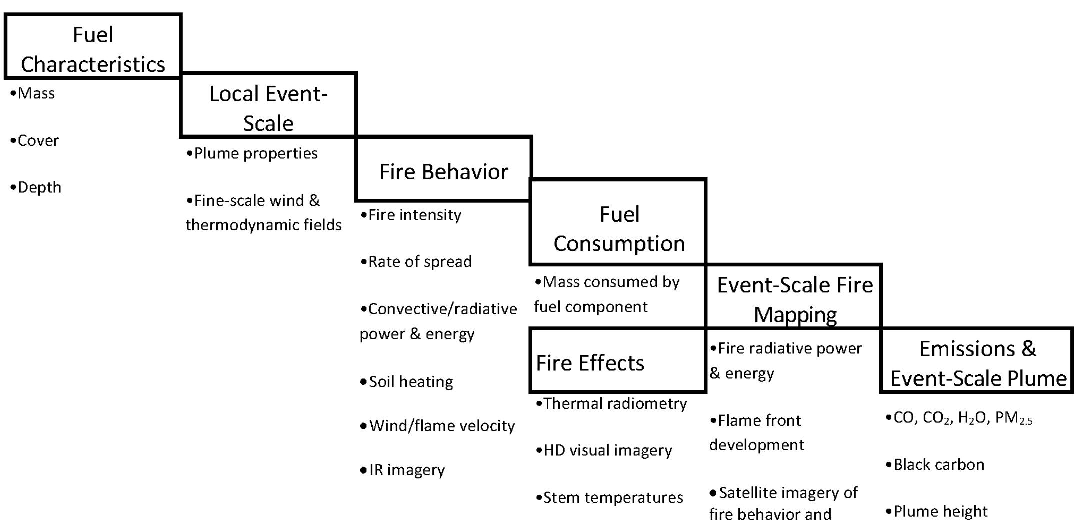


Figure 3.7-21: The main data collection goals for the RxCADRE program in schematic form.

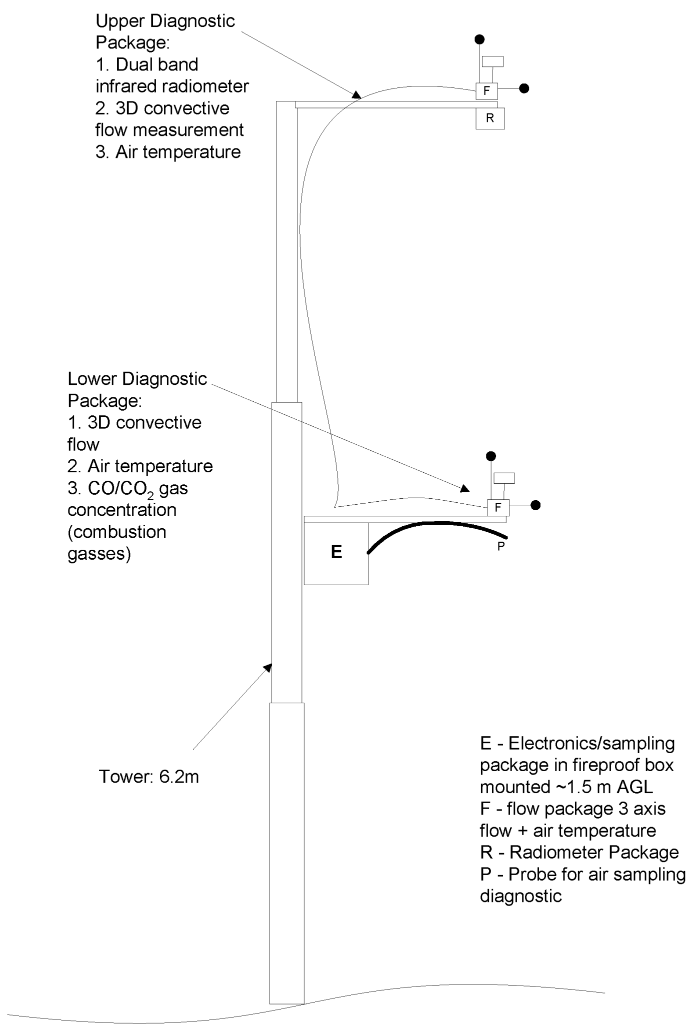


Figure 3.7-22: A diagram of the data collection packages built by RIT for the collection of in-fire data. We built 10 packages of this type for experiments in 2011 and 2012.

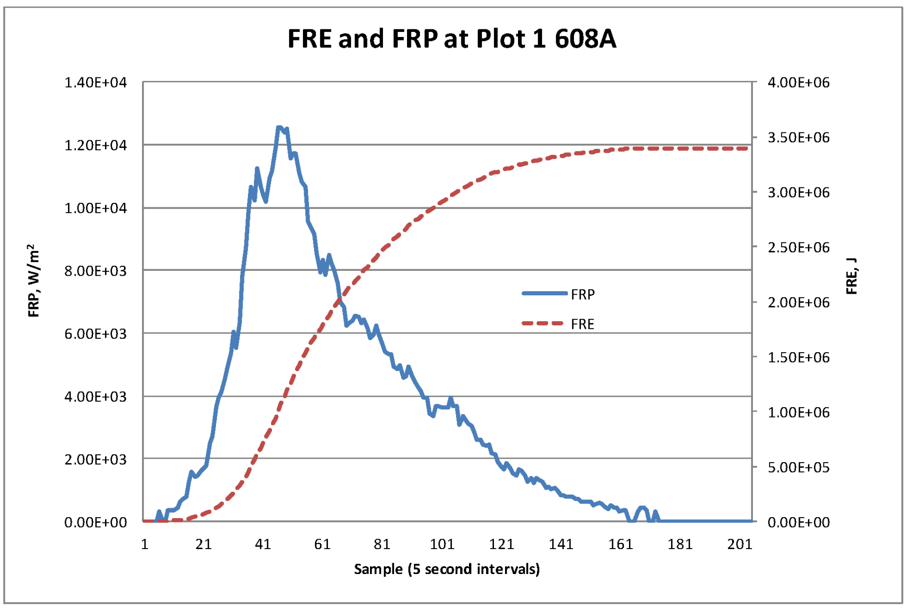


Figure 3.7-23: Surface-leaving radiant flux density as measured by the dual band IR radiometer deployed on one of the diagnostic towers. This data is used for calibration of the airborne WASP instrument as well as for fire behavior and fire effects research.

3.8 Dynamics of the Lake Kivu System: Geological, Biological and Hydrographic Impacts on Biodiversity and Human Wellbeing

Sponsor: John D. and Catherine T. MacArthur Foundation

Principal Investigator(s): Dr. Tony Vodacek

Research Team:
Bikash Basnet (CIS - Ph.D.). US Collaborators at other universities: Drs. Bob Hecky, Stephanie Guildford, and Sergei Katsev at the University of Minnesota-Duluth, Dr. Cindy Ebinger at the University of Rochester, and Dr. Chris Scholz at the University of Syracuse. Key Rwandan collaborators: Dr. Gaspard Rywanwinziri at the Centre for GIS and Remote Sensing at the National University of Rwanda, Dr. Antoine Nsabimana at the Kigali Institute of Science and Technology, and Deogratias Nahayo at INES-Ruhengeri. Key European collaborators: Drs. Francois Kervyn and Damien Delvaux at the Royal Museum for Central Africa in Belgium and and Dr. Nicolas d'Oreye at the National Museum of Natural History in Luxembourg.

Project Description:
Lake Kivu lies at the center and high point of the Albertine Rift, and as such is a focal point for biodiversity in the surrounding montane forests as well as for the fish species in the great lakes of Central and East Africa. Our project goal is to understand the interplay and feedbacks between volcanism, faulting, and biological processes and human activities on the Lake Kivu system over the two year time period of the project, and over the past 5,000 to 10,000 years before present of volcanism, faulting, and climate change. Our work will establish a baseline for assessing human-induced and tectonic-induced change in the Lake Kivu rift system within the greater Albertine Rift. Our studies provide a framework to evaluate biological refugia hypotheses for the low-diversity of endemic cichlids, and to assess human impact on lake eutrophication. This baseline and pre-historic knowledge is expected to impact policy decisions by Rwanda and the DR Congo as these governments deal with natural resource use, overuse, protection, and recovery in the region. The specific scientific field surveys and analyses made during this project to meet these objectives are seismic reflection surveys of the lake sediment, lake sediment coring, installation of regional seismometer and GPS monitoring stations, and remote sensing analysis of change in the watershed.

Project Status:
Our US collaborators have collected and are now analyzing seismic reflection surveys of Lake Kivu sediments (Scholz), sediment cores from Lake Kivu (Hecky), and terrestrial seismic data (Ebinger). Although these activities are not in realm of traditional remote sensing, each of our collaborators use various imaging modalities to accomplish their work. At DIRS, we generated an assessment of landcover change in the Lake Kivu region. The study was informed by previous work done by our Rwandan collaborators at the Centre for GIS and Remote Sensing at the National University of Rwanda. PI Vodacek has been appointed as advisor to the Centre by the Vice Rector to strengthen educational and research ties. In the land cover assessment, land cover classes were determined for cloud-free Landsat mosaic scenes formed for 1987, 2001 and 2010 (see Figure 3.8-24). By classifying each scene independently and then determining change, it is possible to analyze the spatial details of urbanization or loss of forest cover, for example, as they may impact conservation of natural vegetation at specific sites or regionally (post-classification change detection).

Our results illustrate that significant land cover change has taken place in the region over the past 25 years as a result of human migration and changes to agriculture practices. The major landcover changes in the area include rapid deforestation in western Rwanda and urbanization of the Goma/Gisenyi area at the north end of the lake. One result relevant to terrestrial biodiversity is the apparent recovery of some forested area on the DR Congo side of the lake. The total amount of forested land in 2010 is little changed from 1987 despite obvious loss of large areas of the Gishwati and Makura forests in Rwanda to the east of Lake Kivu. This loss appears to have been balanced by an increase in the marginal forest in DR Congo. It may be that the displacement of people in DR Congo due to political instability, has decreased marginal farming activities adjacent to the forest west of the rift valley, leading to some recovery of forested land by 2010. Further analysis is needed to confirm this result. This work also documents the near complete loss of a small forest at the central high spot of Idjwi Island (DR Congo) in Lake Kivu. To our knowledge this deforestation has not been previously identified in the scientific literature and has likely consequences for local biodiversity and water quality.

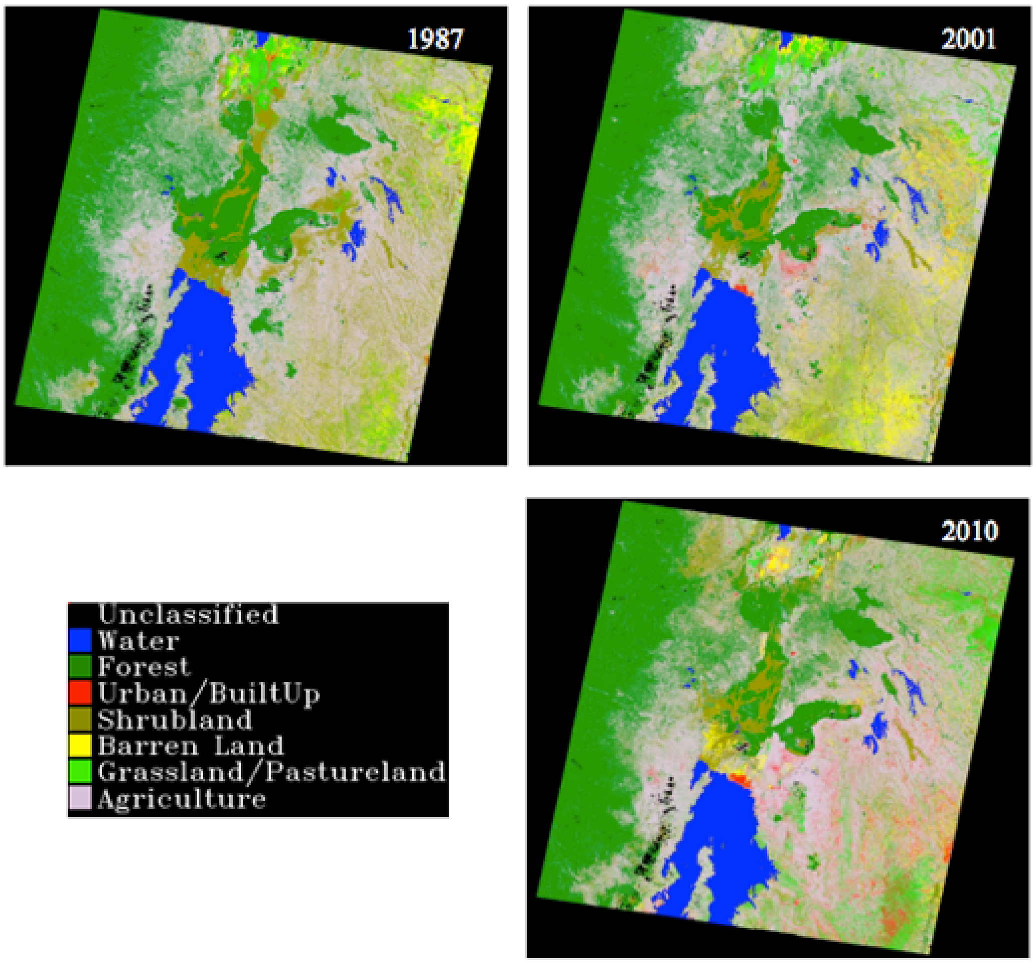


Figure 3.8-24: Land cover classifications derived from Landsat images of the Lake Kivu region for 1987, 2001, and 2010. Unclassified areas (black) were cloudy in each scene. North is up.

3.9 DDDAS for Object Tracking in Complex and Dynamic Environments (DOTCODE)

Sponsor: Air Force Office of Scientific Research

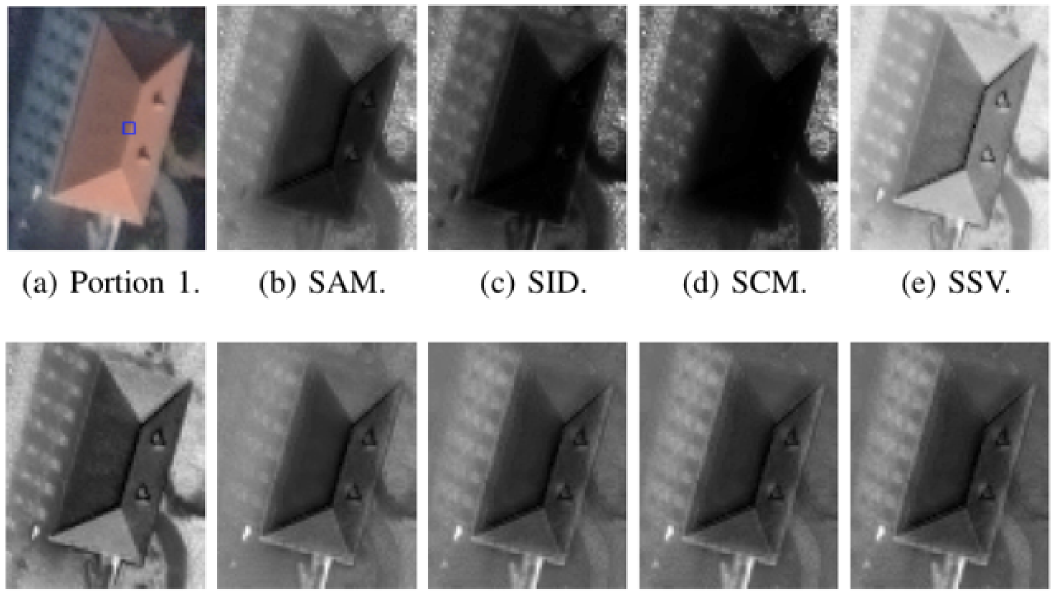
Principal Investigator(s): Dr. Anthony Vodacek

Research Team: Bin Chen (CIS - Ph.D.), Burak Uzkent (CIS - PhD.), Tingfang Zhang (CIS - M.S.), Dr. John Kerekes, Dr. Matthew Hoffman

Project Description:
The problem of tracking an object moving in a dynamic urban environment is complex. Two emerging capabilities that can help solve this problem are adaptive multimodal sensing and modeling with data assimilation. Adaptive multimodal sensing (Dr. Kerekes has previous funding on this topic) describes sensor hardware systems that can be rapidly reconfigured to collect the appropriate data as needed. Imaging of a moving target implies some ability to forecast (model) where to image next so as to keep the object in the scene. Forecasts require models and to help solve this prediction problem, data assimilation techniques can be applied to update executing models with sensor data and thereby dynamically minimize forecast errors. The Dynamic Data-Driven Applications Systems (DDDAS) paradigm is well suited for solving this problem, where sensing must be adaptive to a complex changing environment and where the prediction of object movement and its interaction with the environment will enhance the ability of the sensing system to stay focused on the object of interest. The anticipated outcome of the proposed work is the creation and demonstration of a modeling system to control adaptive imaging within a dynamic synthetic image dataset.

Project Status:
We are working on several aspects of the problem in parallel. PI Vodacek and student are working on image characterization, Co-PI Kerekes and student are testing approaches to tracking using spectral/polarimetric data, and Co-PI Hoffman and student are implementing tracking algorithms. Rather than relying on actual data we are working with the DIRSIG scene generation model for testing object tracking (cars) with multimodal data (multispectral and polarization). We are currently working with a 30 second (1 frame per second) movie of a residential area with moving vehicles. Initial tracking efforts for the DIRSIG scene are led by Co-PI Kerekes who is supervising an MS student. A key finding from this work is the valuable utility of feature-aided tracking rather than motion-only tracking, making us more confident in our spectral/polarimetric adaptive sensor approach. The MS student has also performed valuable analysis of the utility of polarimetric data for object detection and the impact of image noise on tracking performance. This will lead to further study of utility and the impact of image quality on tracking performance. Co-PI Hoffman is working with a Ph.D. student to expand upon the tracking model and has begun an effort to improve the robustness of the system when the car is obscured by adding control in modifying the observation covariance for shape, position, and velocity separately.

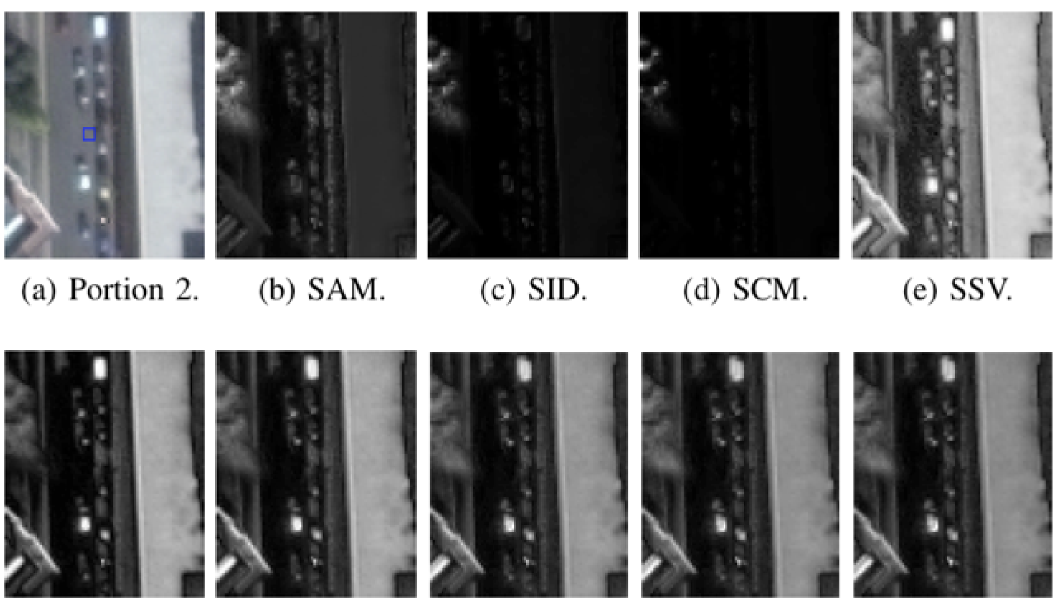
Another component of our approach is to build up a spectral knowledge of the background scene of the object being tracked. This information about the changing image characteristics of the object's current and near-term predicted background, including potential confusers and obscurations, will eventually be used to make decisions on sensor tasking to fully exploit the adaptive nature of the sensors. We have begun to address the problem of image understanding (classification) in high-resolution urban scenes using a spectral similarity approach. This image analysis is being done by a Ph.D. student supported by the project and supervised by PI Vodacek. The approach exploits both spectral magnitude and direction and provides accurate and desired measurement of the spectral similarity in high-resolution scenes. We will continue to test our approach to evaluate its performance and ease of use and assess its application beyond the illumination problem (see Figures 3.9-25 and 3.9-26).



(a) Portion 1. (b) SAM. (c) SID. (d) SCM. (e) SSV.

(f) ED. (g) ATD, w=3. (h) ATD, w=5. (i) ATD, w=7. (j) ATD, w=9.

Figure 3.9-25: (a) A rooftop of one material with different illumination conditions. Some existing target and segmentation algorithms are moderately successful in recognizing the roof as a single material (b-d) while others fail (e-f). Our algorithm (g-j), with a tunable shape variable, returns a consistent score over the whole rooftop.



(a) Portion 2. (b) SAM. (c) SID. (d) SCM. (e) SSV.

(f) ED. (g) ATD, w=3. (h) ATD, w=5. (i) ATD, w=7. (j) ATD, w=9.

Figure 3.9-26: (a) A portion of a typical cluttered street scene with a rooftop, cars on pavement, and a tree. Many existing target and segmentation algorithms fail to segment the targets well (b-d) while others do (e-f), including our algorithm with the shape variable w=7 (i). Combining the results from Fig. 3.9-25 and 3.9-26, our algorithm is the only metric to perform well for both urban scenes.

3.10 Information Products Laboratory for Emergency Response

Sponsor: NSF

Principal Investigator(s): Dr. Jan van Aardt

Research Team: Don McKeown, Jason Faulring, Shagan Sah (CIS - MS), Bin Chen (CIS - PhD), Weihua Sun (CIS - Ph.D.)

Project Description:
The Information products Laboratory for Emergency Response (IPLER) was established in 2009 through a grant from the National Science Foundation (NSF) with a focus on bridging the knowledge gap between remote sensing technology and service providers and information product end users; in essence educating technologists on the needs and constraints of users and educating users on the capabilities of remote sensing technology. IPLER researchers are actively engaged in the development of new information tools and processes that use remotely sensed imagery as a major ingredient. Some of these include:

- Automated detection and mapping of temporary shelters (blue tarps) using the CIS WASP (Wildfire Airborne Sensing Program) sensor
- Automated building damage assessment using light detection and ranging (lidar) data
- Automated wildfire mapping using WASP
- Automated flood mapping using WASP
- Delivery of georeferenced multispectral airborne imagery in realtime (WASP)
- Proof of concept radiological ingestion pathway assessment tool, based on spaceborne RapidEye imagery
- Integrated watershed modeling (IPLER partner University at Buffalo)
- Spring runoff flooding analysis (IPLER partner University at Buffalo)
- Post wildfire erosion assessment (IPLER partner University at Buffalo)

Through IPLER, RIT has established partnerships with UB, the Institute for the Application of Geospatial Technologies (IAGT), ImageCat, Kucera International, Monroe County Office of Emergency Management, and the New York State Department of Homeland Security and Emergency Services (NYS DHSES), among others. These partnerships in particular have been the bridge allowing IPLER to provide support to actual disaster scenarios. A summary of IPLER responses and major exercise activities is shown in table 1 below, followed by a brief description of the past year's activities.

Irene and Lee Flooding Lessons Learned
In the closing days of August 2011, as hurricane Irene moved up the east coast, IPLER offered to support NYS OEM with imaging of communities along the Schoharie Creek watershed, which experienced a 500-year flood as a result of the storm. RIT working with Kucera International, collected imagery over 28 square miles and began delivery of imagery via ftp server to the NYS OEM within 4 hours after collection A mere week after the Irene flood, the remnants of tropical storm Lee pounded PA and the southern tier of NY with up to 10 inches of rain. The resulting flood greatly exceeded previous records and forced the evacuation of an estimated 100,000 persons in NY and PA. 20,000 were evacuated in the city of Binghamton NY alone. Again IPLER responded, and with support from NYS DHSES and FEMA, executed a rapid aerial mapping

Event	Date(s)
Haiti earthquake	January 2010
New Zealand earthquake	March 2010
Japan Earthquake and Tsunami	March 2011
NYS ingestion pathway exercise	May 2011
Hurricane Irene	August 2011
Tropical storm Lee	September 2011
North Border Marine Interdiction Operation full-scale exercise	May 2012

Table 3.10-1: A summary of past IPLER activities.

of the hard hit cities of Binghamton and Johnson City on September 9. Flying below the cloud layer that is impervious to satellite imagers, the RIT sensor on the Kucera aircraft collected very high resolution images of the flood in progress. Imagery was available for download 4 hours after collection and a mere 12 hours after authorization was given to proceed. IPLER collected imagery of flood damage and actual flooding in progress. Figure 1(a) shows post-flood damage to the village of Prattsville following Irene. Notice the displaced building structures. Figure1(b) shows a flood depth contour map superimposed on an image of the flood underway in Binghamton during the tropical storm Lee event.

On 20 December 2011, an ”after-action” meeting was held at the headquarters of IAGT, located on the campus of Cayuga Community College in Auburn New York. Emergency responders at the local and state level provided insight for system developers and researchers, as did private sector participants. The ”debrief” provided both informal observations and discussion and a more facilitated process of participant response to questions provided to participants prior to the meeting. Some key findings from the meeting included:

- Imagery was excellent tool for communicating scope of disaster to senior leadership
- Vertical ortho-imagery has limitations for viewing flood damage (view of building sides)
- Timing relative to flood event is important (peak vs. past peak)
- Imagery data volume is challenging for transmission even over high speed internet
- Imagery has good potential for locating contamination plumes

Enhanced Real-time Data Downlink Development
IPLER developed an enhanced portable ground station enabling rapid deployment of the realtime imagery data downlink to locations other than the RIT campus. Figure 2 shows the installation of the portable ground station on the Monroe County Emergency Operations Communications Vehicle.

Partnership with Syracuse University (IPLER Supplement)
IPLER received additional funding from the NSF to join with the ”Wireless Grids Innovation Testbed” (WiGiT) at Syracuse University School of Information Studies (iSchool) to develop and demonstrate an integrated imagery collection and dissemination system using IPLER remote sensing technology combined with the innovative intelligent Deployable Augmented Wireless Gateway (iDAWG) with the ability to capture and share multiple wireless transmission media, including police, fire, EMS, municipal, private, cellular, CB, bands and others. The Advanced Situational Awareness System (ASAS) shown in Figure 3 will demonstrate the delivery of situational awareness to disaster managers and response personnel through a novel wireless data dissemination backbone, or wireless grid. Information gathered by advanced airborne remote sensing and real-time data processing systems can, through the ASAS, seamlessly deliver actionable information products to a diversity of users including county emergency managers, law enforcement, first

responders, and community groups. This demonstration project will also provide both PFI programs with essential insight from emergency response practitioners dealing with the operational implications of the new technologies, in both urban and rural communities, thus enabling more effective response capability and fruitful future commercialization opportunities.

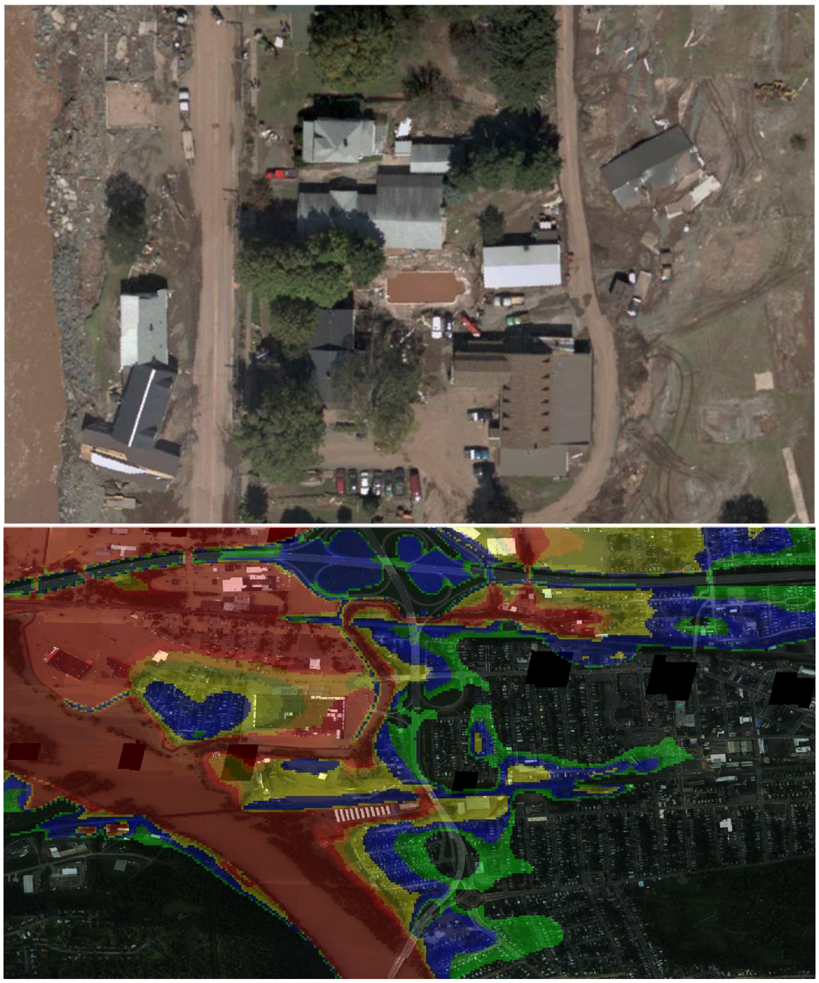


Figure 3.10-27: (top) Post-flood damage to the village of Prattsville following Irene (bottom) A flood depth contour map superimposed on an image of the flood underway in Binghamton during the tropical storm Lee event

Figure 3.10-28: An example of the portable ground station, as installed on the Monroe County Emergency Operations Communications Vehicle.

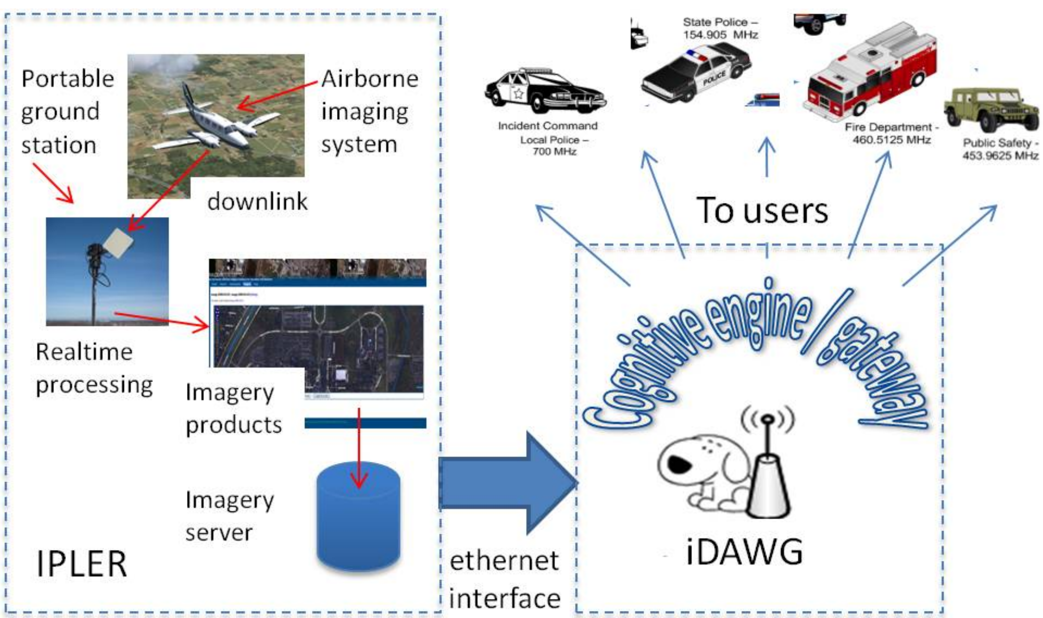


Figure 3.10-29: An example of the Advanced Situational Awareness System (ASAS), an IPLER collaboration with Syracuse University

2012 IPLER Spring Meeting and Workshop

IPLER and the UB Center for Geohazards Studies jointly hosted a major workshop on the application of remote sensing for disaster response and the science of geohazards on May 30-June 1, 2012, at the RIT campus. Workshop highlights included keynote speakers from federal agencies and the commercial sector:

- Dr. Brenda Jones (United States Geological Survey; Disaster Response Coordinator)
- Dr. Matthew Pritchard (Cornell University; Earth and Atmospheric Sciences)
- Mr. Ron Eguchi (ImageCat Inc.; President and CEO)
- Mr. Shay Har-Noy (TomNod Inc.; CEO)

The workshop also featured talks and roundtable discussions, including student presentations on their latest research and updates on IPLER remote sensing support to the 2011 Japan earthquake and tsunami and recent flooding in New York State (storms Irene and Lee). Other highlights included:

- Workshop dealing with the use of remote sensing systems (sensor selection, tasking, and data processing)
- Demonstration of a realtime airborne remote sensing system featuring image collection, processing, and dissemination to a display in a reception room on the RIT campus.
- On-site workshop on disaster response in Native American communities, hosted by the UB Center for Geohazards Studies at the Seneca Nation of Indians

Federal and State Agency Outreach

The Northern Border Security Group and U.S. Department of Homeland Security/Federal Emergency Management Agency Region II hosted Northern Border Marine Interdiction Operation (MIO) Full-Scale Exercise (FSE) on May 10, 2012, in Monroe County, NY, and on Lake Ontario. The purpose of the FSE was to provide an opportunity to practice interagency communications and coordination of a maritime response to a terrorist threat occurring in the Lake Ontario area near the border of Monroe County. The exercise will explored interaction of plans and systems among several New York State counties, State agencies, and their Federal agency counterparts. IPLER was invited to participate as an experiment to evaluate the use of airborne thermal infrared imagery to detect and track boats. In spring of 2012, IPLER presentations were delivered to NYS Department of Environmental Conservation and DHSES in Albany to promote the use of remote sensing for monitoring the exploitation of natural gas from the Marcellus Shale (hydro-fracking) and disaster response.

Student Research

CIS MS student Shagan Sah and PhD students Bin Chen and Bikash Basnet performed graduate research in context of the IPLER project:

- Shagan developed an approach to rapid land cover classification, following a disaster event, using multi-temporal, coarse spatial resolution MODIS imagery in conjunction with high spatial resolution RapidEye imagery. Shagan presented his results at the 2012 SPIE conference (A multi-temporal analysis approach for land cover mapping in support of nuclear incident response; Shagan S., Jan A. N. van Aardt, D.M. McKeown, and D.W. Messinger; Proceedings of SPIE Algorithms and Technologies for Multispectral Hyperspectral, and Ultraspectral Imagery XVIII; May 1, 2012).
- Bin Chen's work focuses on classification and change detection in high resolution urban scenes. This work seeks methods for spectral similarity that take into consideration the unique properties of high resolution urban scenes. Initial results have successfully addressed illumination change and shadowing in an urban scene and was presented at IGARSS 2012.

- Bikash Basnet's project title is "Mapping land cover dynamics in the Albertine Rift". This study is examining methods of classification and post-classification change detection of multitemporal Landsat data of the Albertine Rift from the 1970s to present and seeks to develop methodology for maximizing the information content in this frequently cloudy region. Initial results was be presented at the 1st EARSeL Workshop on Temporal Analysis of Satellite Images in 2012.

Project Status:
The project is in its final year, during which we will focus on the completion of the ASAS collaboration with Syracuse University.

3.11 NEON Post-Doc

Sponsor: National Ecological Observatory Network (NEON)

Principal Investigator: Dr. Jan van Aardt

Research Team: Kerry Cawse-Nicholson, David Kelbe, Paul Romanczyk, William Wu

Project Description:
The Digital Imaging and Remote Sensing group (DIRS) in the Chester F. Carlson Center for Imaging Science (CIS) at Rochester Institute of Technology (RIT) is focusing on research related to algorithms for waveform Light Detection and Ranging (LiDAR) processing, extraction of structural products, and development of preliminary workflows for generating hyperspectral/LiDAR data fusion products. DIRS is making use of the skills of a full-time post-doctoral researcher (Kerry Cawse-Nicholson) funded by the National Ecological Observatory Network (NEON) over the two-year period of performance of this project. Various PhD students are also performing their graduate research in this domain.

Detailed research objectives and specific areas of research to be investigated include:

- Evaluate approaches to processing waveforms to reduce noise, and correct for the effects of pulse width and slant angle.
- Obtain accurate retrieval of vegetation parameters (e.g., leaf area index, crown volume, canopy height, vertical profiling, and biomass estimations).
- Assess accuracies in estimating vegetation parameters using waveform and pseudo-waveforms, extracted from discrete LiDAR distributions, using simulated vegetation scenes.
- Apply preliminary science algorithms to prototype data sets acquired by the NEON Airborne Observation Platform (AOP) Team.

Project Status:
The project is in its first year of a two year time allocation. In March 2012, Kerry (above-mentioned post-doc) started her post at RIT, and has been evaluating the scaleability of popular leaf area index (LAI) metrics, using synthetic scenes. Kerry is also developing an empirical model to correct for the effects of attenuation due to canopy in waveform LiDAR. A large part of this project also involves working as a team with a group of PhD students.

William Wu (CIS - PhD) defended his PhD on August 14, 2012. He created a waveform pre-processing chain, which includes noise reduction, deconvolution, waveform registration, and angular rectification. An

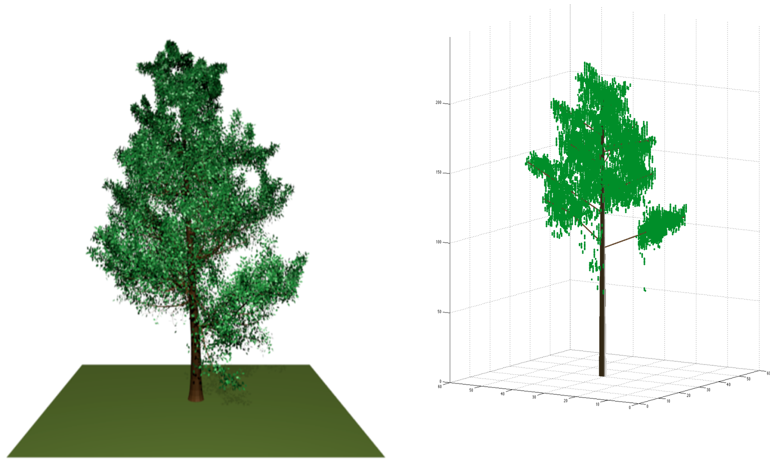


Figure 3.11-30: An example of 3D tree construction from waveform LiDAR signal, based on a virtual tree (left) and the end-result (right).

illustration of the improvement in the resulting waveform is given for biomass estimates, and in 3-D tree branch reconstruction (see Figure 3.11-30). This has been an important contribution to the NEON project, since the waveform preprocessing chain will be used as a first step in the development of other algorithms by the RIT team.

Paul Romanczyk (CIS - PhD) has created a synthetic forest in DIRSIG (Digital Imaging and Remote Sensing Image Generation tool) to evaluate the properties of waveform LiDAR. The trees are created based on real tree measurements and spectral properties in order to represent a realistic simulated scene, which are shown in Figure 3.11-31. Paul has investigated which tree properties (twigs, leaves, branches etc.) significantly affect the waveform, and concluded that twigs and leaf stems do not significantly affect the backscattered light. This synthetic dataset will be useful to the RIT research team for algorithm design and testing in the case where the truth is known.

David Kelbe (CIS - PhD) has been working with data from a ground-based discrete LiDAR. He has developed a tree trunk detection algorithm, using the LiDAR point cloud. This method is able to detect tree location, diameter and angle of growth, and has been tested on real and synthetic data (see Figure 3.11-32). This work will be incorporated into the synthetic scene design for automatic realistic forest environment simulation.

Next Steps:

In August 2012, the RIT team took part in an extensive data collection in Harvard Forest, Massachusetts. This corresponded with a NEON airborne campaign that will produce hyperspectral, discrete LiDAR and waveform LiDAR data. The combined work of the RIT team will aim to link ground-based and airborne LiDAR, use the collected data for a more accurate synthetic scene design, and estimate important forestry metrics such as LAI, tree height, biomass etc.

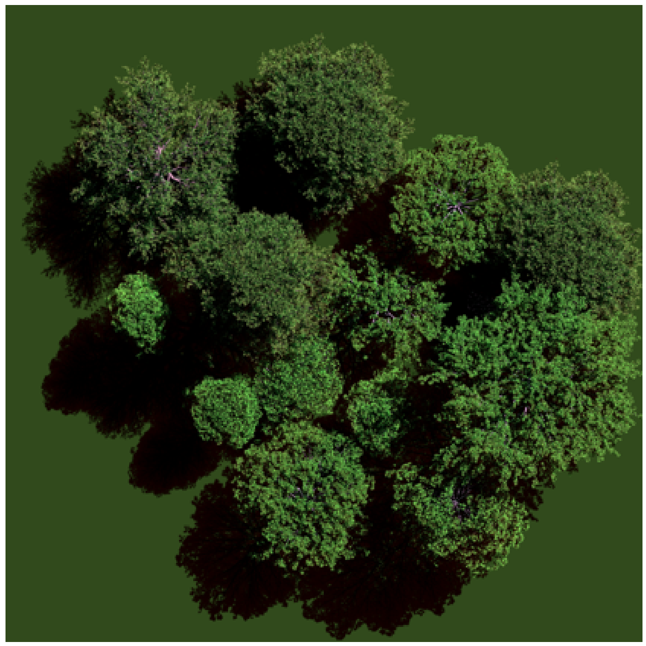


Figure 3.11-31: An example of a realistic virtual forest scene, used for waveform LiDAR simulation in the DIRSIG simulation/modeling environment. The scene contains realistic red maple and red oak tree structures and spectra.

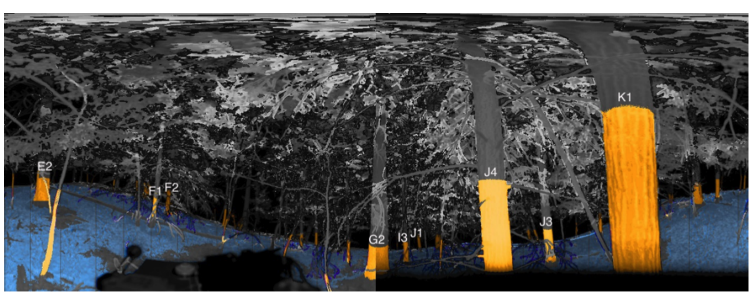


Figure 3.11-32: Orange detected tree trunks superimposed over point cloud and blue Digital Elevation Model (DEM).

3.12 Modeling Research for Performance-driven Multi-modal Optical Sensors

Sponsor: Air Force Office of Scientific Research (AFOSR)

Principal Investigator(s): Dr. John Kerekes, Dr. Zoran Ninkov, Dr. Alan Raisanen

Research Team: Lingfei Meng (Ph.D. student) and Tingfang Zhang (M.S. student); collaboration with Numerica, Inc., Dayton, Ohio

Project Description:
The objective of this project is to perform basic research in the development and use of integrated microelectromechanical systems (MEMS) devices coupled with optics and solid state focal plane array technology for adaptive exploitation-driven multi-modality sensing suitable for ISR applications. In particular, we are investigating adaptive sensor designs that enable co-registered electro-optical imagery, video, polarization and spectral sensing in a robust compact unit. These designs are being explored together with research into real-time exploitation algorithms that can adaptively control the sensing modality and field-of-view to enable object tracking and monitoring specific to the situation. These device and algorithm research efforts are being conducted together with scene phenomenology modeling and simulation tools to perform comprehensive system-level performance analyses and demonstrations of the potential for the concepts to lead to transformational ISR capabilities.

Our approach for this effort is to explore feasible optical device constructs which through further research and development could lead to integrated imagery (both intensity and polarization), video and spectroscopic sensing together with the algorithms and scene phenomenology for adaptive sensing and tracking of objects of interest in a cluttered environment. This approach combines three interrelated research veins. 1) Sensor and Device Research. This research thrust is exploring conceptual designs and component modeling for integrated multi-modality optical sensors based on MEMS, digital micromirror, integrated Fabry-Perot, and high resolution lithography technologies. 2) Exploitation Driven Adaptive Sensing. This effort is working on the basic science of algorithms necessary to exploit, track and adaptively control the sensing parameters based on the scene phenomenology, and observational geometry, and target information. 3) System Performance Modeling and Analysis. This third research vein provides the framework using DIRSIG and Matlab for end-to-end system modeling of the device concepts and processing algorithms and enables system level trade-off studies and performance predictions.

Project Status:
This year was the fourth year of the project. The work focused on the modeling and analysis of adaptive polarimetric systems and the exploration of algorithms for enhanced tracking using polarimetric and spectral information. The adaptive polarimetric sensing work by Meng was expanded to include sensor viewing geometry related scene variation, the sensitivity of DOLP to SNR, and detection performance modeling. The tracking work included analysis of simulated spectral polarimetric imagery as well as real airborne imagery collected by RIT's MAPPS sensor. Initial prototypes of a MEMS FP single-pixel device were fabricated.

The project completion date is 31 August 2012. Remaining tasks include evaluation of prototype MEMS FP devices and completion of the Meng and Zhang theses.

3.13 Phenomenology Study of Feature Aided Tracking of Dismounts

Sponsor: Air Force Research Laboratory (AFRL) - Sensors Directorate

Principal Investigator(s): Dr. John Kerekes

Research Team: Jared Herweg (CIS - Ph.D.) and Dr. Emmett Ientilucci

Project Description:
The objective of this project is to investigate the phenomenology sensible by hyperspectral imagers for the purpose of detecting, identifying, and tracking humans in a cluttered environment. The Air Force is interested in this technology as part of combating terrorism and facing the increased challenges of fighting in urban environments.

Project Status:
The project completion date is 31 August 2012. A primary result of the project was the PhD thesis by Jared Herweg entitled "Hyperspectral Imaging and Association Phenomenology of Pedestrians in a Cluttered Urban Environment." A journal article has been submitted for review with a goal of having a peer-reviewed publication on the project.

3.14 Advanced Multi-modal Scene Development

Sponsor: Raytheon Corporation

Principal Investigator(s): Dr. John Kerekes

Research Team: Chris De Angelis and Dr. Scott Brown

Project Description:
This project is a continuation of work initiated in 2010 to expand the DIRSIG scene known as MegaScene. The expanded scene encompasses an area 6 km x 8 km supporting renderings at 1 m resolution. A high-rise urban area has been inserted, as well as a shipping port along Lake Ontario. In addition, more variability has been introduced into the material spectra and care taken to update details such as sidewalks, curbs, and building features. Sample renderings have been made for panchromatic, hyperspectral, and lidar sensors. In addition, through a collaborative effort with DigitalGlobe, a WorldView-2 satellite image was obtained of the area northeast of Rochester used as the underlying scene content of the original MegaScene. Work has been initiated to explore statistical comparisons between the real image and corresponding parts of a DIRSIG rendered image. The DIRSIG scene, WV2 image, and associated files have been delivered to Raytheon for ongoing evaluation.

Project Status:
The project has been continued with an extended completion date of 31 December 2012. Comparative evaluation of the DIRSIG and real WV2 images is ongoing.

3.15 Semi-Automated Scene Material Property Extraction from Oblique Imagery

Sponsor: Lockheed Martin; NSF AIR Program

Principal Investigator(s): Dr. David Messinger

Research Team: Michael Harris (CIS - MS)

Project Description:
Modeling radiative transfer mechanisms along with the world's geometry allows simulation of the sensor-reaching radiance of a fabricated scene. RIT's Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool provides an environment to model source geometry, atmospheric propagation, wavelength and geometry dependent spectral characteristics, and sensor operation. DIRSIG can be used to complement real ground truth in the exploration of target detection or classification algorithm performance, and to simulate the effects of sensor design specifications on image quality. Currently, base models of every type of vehicle, house, tree, industrial building and the like are fabricated by hand using a variety of Computer Aided Design (CAD) tools, and each material is specified. These base models are then attributed with varying materials and orientations and instantiated manually throughout the scene. Though scenes on the order of several square km have been generated, it is cost prohibitive to do this often or dynamically for real world scenes. Automating this procedure would allow fast replication of real-world environments and structures, greatly increasing the diversity, complexity, and efficacy of simulation. This task requires the automatic generation of two inputs, namely the source geometry of the scene to be rendered, and a classmap of material type coupled to each facet of the geometry to leverage the DIRSIG material property database. Both of these inputs can be derived from images of the desired scene to be rendered.

Toward automating construction of 3D models RIT has developed a workflow to automate point cloud extraction from a series of images based on point correspondences and photogrammetric principles. Recently, the maturation of this work has allowed production of geo-located structural models. These algorithms make it possible to capture aerial imagery of a scene from flyovers or passive remote monitoring, and quickly output a structural model useful for simulation or other tasks such as urban development or mission planning where knowledge of 3D scene geometry is critical. This represents a leap forward in automatic generation of source geometry for simulation.

The remaining work in automatic generation of complete models for simulation addresses the second input component to DIRSIG, that is the material label such that facets can be rendered with appropriate material properties stored in the DIRSIG library. In order to quickly construct detailed real world scene models, oblique aerial imagery can be leveraged along with a supervised classification algorithm. The resulting classmap can then be combined with the co-registered 3D point clouds to ultimately label each facet of the model with a material. Progress toward this end will be discussed in the following.

Project Status:
A workflow has been developed toward material recognition in aerial images as follows. The user first selects training and test data from contiguous material regions in a single image and provides a class label, *i.e.* brick, asphalt *etc.* Next these regions are tiled and a set of descriptor features are extracted. The feature space of each class is produced by amalgamating the feature vectors of each tile of a particular class. The features representing each tile of the test set are then compared using an appropriate minimum distance metric to the overall class feature spaces. The feature spaces can be represented in general as distributions, histograms, or in other ways. Figure 3.15-33 shows a schematic of the overall classification procedure.

Critical to the classification process is the selection of a feature set that induces separability between pixels of different labeled classes. The data available (to be discussed in sections following) is 3 band RGB imagery, and so classification relies primarily on the ability of the feature set to extract dominant texture components. Incorporation of the color components has also been investigated.

In the current workflow a filtering scheme utilizing Gabor filters has been developed. This method extracts the energies of a textured subimage from the outputs of variously oriented narrow bandpass filters. In this way a texture is characterized by its dominant frequency components. Gabor filters have the unique property of spatial and spatial frequency localization, that is domainant frequency components are extracted from a particular subimage location. They possess several tunable parameters which can provide full coverage of the spatial frequency domain. Gabor filters have received much attention due to their resemblance to the receptive fields of the human visual system.

Progress has been made in the investigation of the Gabor filter feature set for supervised material classification. A number of filter configurations have been investigated, and image regions classified using two methods. Success metrics have included overall classification accuracy, as well as statistics derived from contingency matrices. The next section will describe the dataset and challenges to classification of oblique aerial imagery.

The dataset used for validation of the material extraction workflow consists of oblique aerial images of about 0.5 ft resolution of a densely populated urban area as shown in Figure 3.15-33. The oblique look angles cause the image objects and textures to undergo substantial illumination changes and projective transformations which can severely warp a textured region. Fine texture structural features such as individual brick lines are not resolved. Occlusions are apparent due to the high building density, and clutter such as cars and rooftop a/c units can confuse the classifier. This dataset is more than sufficient to test the robustness of the workflow and discriminatory power of the feature set to most real world imaging conditions.

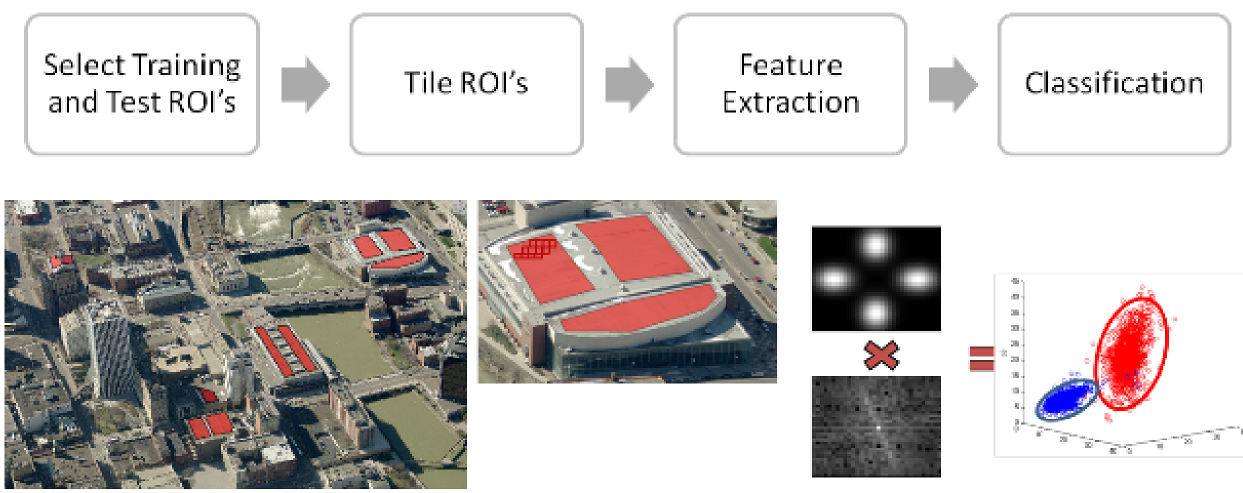


Figure 3.15-33: Schematic of the classification workflow and dataset.

For these experiments Gabor filter banks were designed with angular separation and orientation of 30 degrees leading to the"daisy petal" frequency domain configuration shown in Figure 3.15-34 with 12 filters total. Each trial the center frequencies and frequency bandwidths of each filter were varied and different filter combinations were investigated.

Additionally, in later experiments the intensities of each color band were used, within RGB and the 1976 CIE $L^*a^*b^*$ orthogonal color space. The intensities of each band were normalized and added to the total feature vector as additional dimensions. The textural features in all experiments were derived from a grayscale image formed from a weighted sum of the color components.

Classification was done by computing the Bhattacharyya distance between every test tile and every class

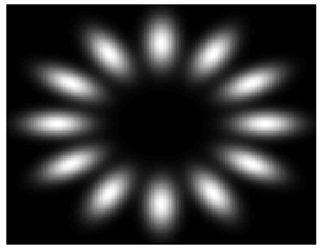


Figure 3.15-34: Gabor daisy petal filter configuration

distribution. Binning each tile and class distribution into marginal histograms was also investigated, but this procedure led to additional constraints in modeling the histograms and was abandoned.

The training and testing data were selected from contiguous blocks of rooves as shown in Figure 3.15-33. Each region selected contained equal parts testing and training tiles. About 39 roof regions were chosen, consisting of several manually labeled material classes. The tile window size varied from 16 by 16 pixels up to 64 by 64, but the results were not heavily influenced by window size changes within that range.

Thus far, a workflow to extract material type from oblique aerial images has been developed, and several filtering schemes for feature extraction have been tested. The next steps should include testing of additional filter designs such as a dyadic configuration. Given the nature of the data, the textural feature components may also benefit from rotation invariance. There are also many other ways of combining spatial and spectral information. Since the textural features were extracted from a combination of RGB bands, they are inherently dependent on the illumination level. Only roof surfaces were classified in these tests due to the level of clutter and lack of contiguous building sides for training data. To extract material type from building siding, windows and other sources of noise may be removed, or some threshold for class membership can be implemented. Finally, more complex classifiers exist such as neural network approaches and other methods to produce higher order discriminant functions.

3.16 Interdisciplinary Advancement of the Theoretical Basis for Lidar Sensing of the Earth

Sponsor: National Aeronautics and Space Administration (NASA)

Principal Investigator(s): Dr. John Kerekes

Research Team: Jiashu Zhang (Ph.D. student), Kim Horan (M.S. student), Dr. Adam Goodenough, and Dr. Scott Brown

Project Description:
This project is a collaboration with geoscientists from the University at Buffalo to expand the scientific understanding of satellite-based lidar sensing of complex surfaces, particularly glacial ice sheets pocketed with crevasses. The research is proceeding by rendering complex surfaces with appropriate scattering models in DIRSIG, and then exploring how those surfaces interact with lidar pulses and the detection process to produce simulated measurements. Relationships between surface characteristics and simulated data are being studied to better understand the sensitivity of measurements to known and unknown variations on the surface. The work is motivated by the upcoming ICESat-2 satellite mission, and collaboration is ongoing with the ICESat-2 program office.

Project Status:
Initial renderings of complex ice surfaces for panchromatic and lidar sensors were made in this first year. The project is ongoing until the summer of 2014.

3.17 Infrared Signatures of Liquid Contaminated Surfaces

Sponsor: Physical Sciences Incorporated (Army STTR)

Principal Investigator(s): Dr. John Kerekes

Research Team: Dr. Mike Gartley and Chris DeAngelis

Project Description:
This project was a Phase I STTR with Physical Sciences, Inc., under funding from the U.S. Army Edgewood Chemical & Biological Center. Longwave infrared spectral emissivity measurements were made for samples of SiO2 (sand) with and without 0.3% (by weight) of SF96 (poly dimethyl siloxane) oil. Two different sand particle size ranges were considered. In addition, model-based predictions were made of the spectral emissivity using the micro-scattering code known as microDIRSIG. Best efforts were made to model the same materials and their characteristics used for the empirical measurements, although assumptions were necessary.

The model predictions used first-principles physics-based scattering models and parameters taken from the literature for the scattering characteristics and indices of refraction for the sand and the SF96. While the model did not have the exact parameters for the materials measured, the comparison showed a consistent trend and significant separability between the spectral emissivity of sand with and without the SF96 present for both the measured and modeled curves. Further collections and modeling of additional materials are recommended in follow-on work.

Project Status:
The project was completed in June of 2012. A Phase II proposal was submitted and was selected for award with an expected start date of November 2012.

3.18 Enhanced Simulation of Scenarios Through the Incorporation of Process Models

Sponsor: DOE

Principal Investigator(s): Dr. David Messinger

Research Team: Jiangqin Sun (CIS - Ph.D.), Weihua Sun (CIS - Ph.D.)

Project Description:
The objective of this project is to define, develop, implement, and test a methodology for connecting process models to synthetic scene elements for the simulation of temporally varying, observable signatures related to nuclear proliferation activities. These simulations can then be used for algorithm evaluation, sensor design studies, as a hypothesis testing tool for analysis, and a variety of other applications. The Digital Imaging and Remote Sensing Laboratory (DIRS) at the Rochester Institute of Technology has developed the Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool over the past 20+ years to

achieve exactly these goals. DIRSIG has a long track record of providing accurate physics-based simulations across several imaging modalities including both the reflective and emissive spectral regimes, polarimetric imaging, and recently, active LIDAR three-dimensional imaging.

The project builds off the technical capabilities of the Digital Imaging and Remote Sensing Image Generation tool (DIRSIG), a physics-based, first-principles radiometric scene simulation tool for generation of synthetic data sets across several modalities (passive reflective and emissive, fully spectral and polarimetric sensors, as well as active, LIDAR systems). These simulations can then be used for algorithm evaluation, sensor design studies, as a hypothesis testing tool for analysis, and a variety of other applications.

The research is defined by two research areas: extraction of features from imagery of existing sites to drive proliferation scenario modeling, and development of the methodology to map the signature impacts of spatial - temporal processes in the DIRSIG scene description.

Project Status:
The extraction of features from multispectral imagery task has focused largely on the extraction of road networks from high resolution (2 m) space-based imagery. The methodology developed takes in as input a multispectral image. With minimal training data selected by the user, the algorithm performs a spatial-spectral flood-fill analysis to identify all contiguous, spectrally similar pixels that are candidate roads. Additionally, this set of road pixels is used as a training set to identify other potential road pixels in the image that may not be connected to the initial training data. This binary map of likely road pixels, which contains many false detections, is then narrowed down using two main steps: a curvilinear detection step and a knowledge-based system. The curvilinear detection step identifies the potential road pixels that also form linear, or slightly curved structures of the appropriate width. This step filters out false detections such as parking lots and large roof buildings. The next step, the knowledge based system, divides these potential roads in a network of nodes and edges. Then, rules are used to connect the edges into the full road network.

Figure 3.18-35 demonstrates the results of this process on a multispectral image collected over Trona, California. Note that there are few missed road segments, and few false detections in this challenging environment. Here, the roads are very similar in spectral character to the background of the image, yet the workflow accurately extracts the desired road network. Additionally, this road network can now be saved as a GIS file for use in the scene simulation workflow.

The other task, focused on simulation of temporal processes in DIRSIG, has moved to a simulation of the Midland Cogeneration Venture power plant in Midland, MI. The DIRS laboratory has conducted other research projects focused on this site and consequently has significant amounts of data, as well as an initial DIRSIG simulation of the site. Here, we extended that simulation to include a process model that maps temporal changes in the ongoing industrial processes at the plant with observable signatures. In this case, the process being simulated is the daily changes in the power output of the plant. The observable quantities related to this process include the number of stacks operating, the number of cars in the parking lot, the temperature and temperature distribution of the cooling pond, and others. Figure 3.18-36 shows a DIRSIG simulation of the Midland plant as would be seen by the RGB bands of the Worldview-2 sensor. This figure shows the extent of the DIRSIG scene, including the primary buildings at the site and the large cooling pond. Figure 3.18-37 shows a DIRSIG simulation of the same scene as would be collected by an airborne thermal infrared framing camera system, such as the RIT WASP system. Here, note that the brightness levels correspond to temperature on the ground. The temperature distribution in the cooling pond was simulated using the ALGE hydrodynamic and thermodynamic prediction model. Additionally, the smoke stacks emit water vapor plumes that can be seen in the thermal imagery.

This process model simulation is meant as a demonstration of how such a model can be directly tied to observable signatures across a wide variety of imaging modalities. Ultimately, this project will move toward analysis of such imagery to understand the challenges associated with estimation of the process model at a denied facility.

Figure 3.18-35: Results from processing a Worldview-2 multispectral image through the road network detection algorithm workflow. RGB image is shown with the detected road network highlighted in red.

3.19 Dynamic Analysis of Spectral Imagery

Sponsor: National Geospatial-Intelligence Agency University Research Initiative

Principal Investigator(s): Dr. David Messinger

Research Team: Jamie Albano, Amanda Ziemann (both CIS - Ph.D.)

Project Description:
Imagery analysis is traditionally performed using the "eyes on pixels" model by visual inspection. While this method is reliable for analysis of known targets of interest, semi-autonomous processing schemes are required to analyze large area coverage imagery in a "search" analysis. Spectral imagery provides a potential opportunity for semi-autonomous analysis based on the large amounts of material-specific information contained in the spectral content of the image. The complex nature of spectral imagery, particularly hyperspectral, necessitates the use of semi-autonomous processing schemes for exploitation. Here, analysis is being carried out on subsets of the image, or "tiles", of appropriate size to ensure sufficient sampling of the data hyperspace while still providing detection of man-made activities. Methods based on the topology of the data are under development and testing for this application. Such methods seek to describe the data cloud from an individual tile without assumptions of normality or linear geometry. For all tests of man-made activity, results will be presented as indicating that a particular tile warrants further investigation,

Figure 3.18-36: DIRSIG simulation of the Midland power plant as would be seen by the Worldview-2 satellite. The RGB bands are shown here.

thus serving as a "cue" for further analysis and / or collection. The key component of the research here is the identification of subsets of the image that are "interesting" in the sense that they contain man-made phenomena.

This project will develop a novel methodology to use the distribution of the data in the full k dimensional hyperspace (where k is the number of spectral bands collected) to identify regions of man-made activity in spectral imagery. By identifying such regions for further interrogation, the robustness of exploitation algorithms will be increased and the efficiency of data processing will also be improved. In this way, the hyperspectral imagery can be used as a cue for further processing, either using the spectral imagery or through other means.

Project Status:

The first year of this program saw progress made in understanding and characterizing the dimensionality of hyperspectral data. A methodology using the Correlation Dimension, as estimated via a Point Density Analysis, was implemented and applied to hyperspectral imagery containing diverse scene contents, including both natural and man-made materials. This method of estimating the dimension from the data

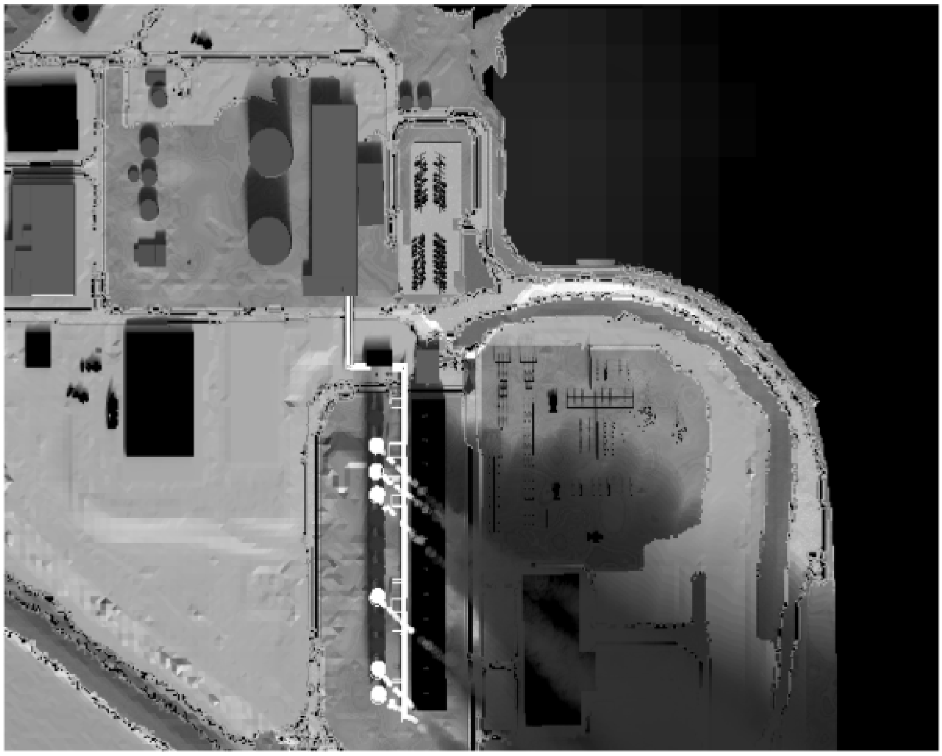


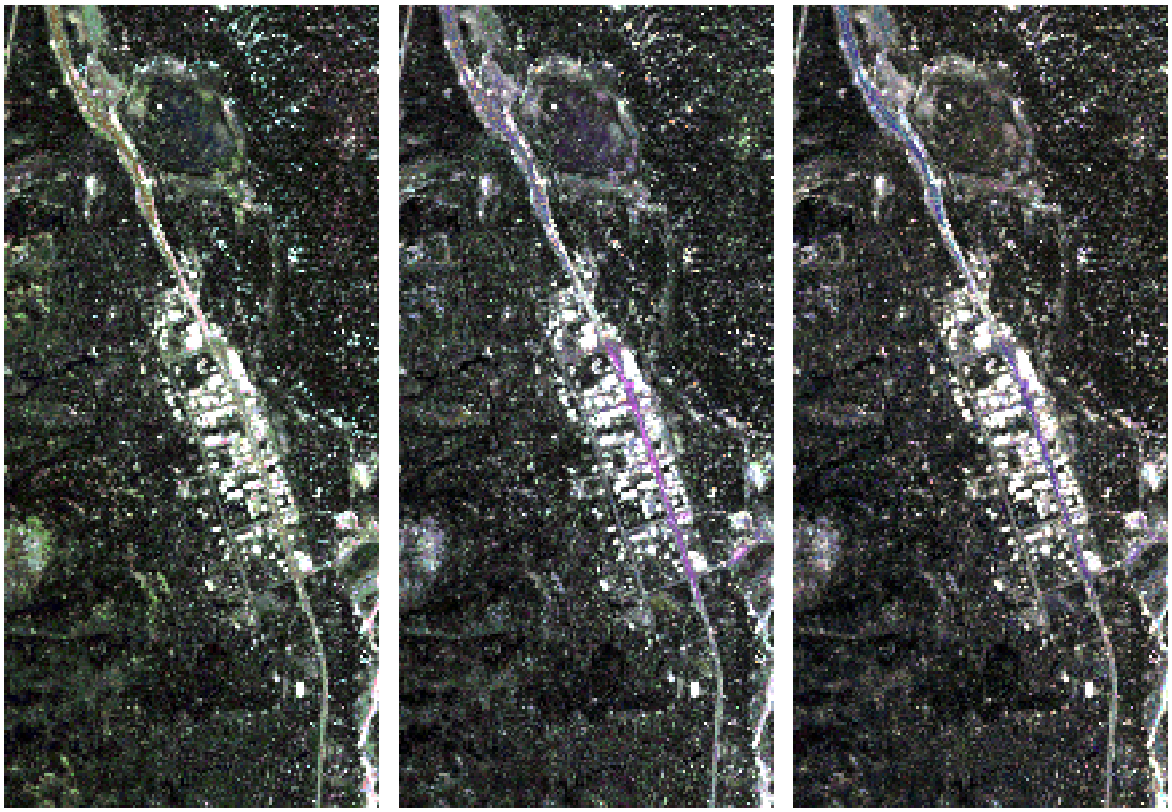
Figure 3.18-37: DIRSIG simulation of the Midland power plant as would be seen by an airborne LWIR system.

itself while not relying on statistical measures provides a unique way to understand how image segments containing single and multiple material types are distributed in the hyperspace.

During the second year, the development of the Point Density Analysis moved the research into the area of change detection in spectral imagery, a particularly challenging problem. It was discovered that features of the Point Density Plot, as a direct measure of the distribution of the data in the hyperspace, could be quantified with respect to changes in the scene content. Analysis was performed to understand the sensitivity of these metrics to the presence of man-made materials in a background of natural materials, which lead to an approach to spectral change detection. Results indicate that the method is applicable to the problem of change detection in spectral imagery and does not require accurate registration or knowledge of the signatures to be detected.

The third year of this research focused on developing the methodology to incorporate several metrics into a feature space allowing the user to perform "interest segmentation" on the image. The image is tiled, and for each tile feature metrics are estimated based on the distribution of the data. These features are then fed to an unsupervised classification scheme to provide a two-class map of the image: "interesting" regions and "non-interesting" regions. The methodology generally correctly identifies regions of potential interest through this feature-space classification, providing an aid to visual and semi-autonomous analysis of large area scenes.

The fourth year of this program focused on revisiting the Topological Anomaly Detection (TAD) algorithm within the context of our novel approaches to graphical models of hyperspectral imagery. Previous work identified strong dependencies in classification algorithm performance based on how the graph model



(a) (b) (c)

Figure 3.19-38: Three false color anomaly maps whose RGB bands are representative of different graph creation techniques. The sample size changes in each image, but all three were created using their respective gray maps for R = kNN, G = mutual kNN, and B = sigma local with $\sigma = 1.5$. (a) sample size = 500, (b) sample size = 1000, and (c) sample size = 2000.

was constructed. A similar approach was taken to understand the dependence of the anomaly detection algorithm. It was ultimately determined that given that the goal of the TAD algorithm is to identify only the background components (and then measure anomalies against those) the algorithm was less dependent on the graph creation methodology as most methods equally identify the appropriate background components based on their close, compacted structures in the hyperspace.

Figure 3.19-38 shows the results of modifying the sample size used in the TAD algorithm as part of the graph creation step. In each case, an RGB image is shown where the Red channel is the anomaly detection result after creating the graph with the k-Nearest Neighbors algorithm, the Green channel used a graph from the Mutual k-Nearest Neighbors algorithm, and the Blue channel used the sigma-weight graph creation technique. In this case, it is shown that the algorithm is not particularly sensitive to the graph creation technique, and thus the algorithm performance should be robust to this variations in this step of the process.

3.20 Spatial / Spectral Large Area Search Tool Development

Sponsor: National Geospatial-Intelligence Agency University Research Initiative

Principal Investigator(s): Dr. David Messinger, Dr. Eli Saber

Research Team: Abdul Haleem Syed(CIS - Ph.D.)

Project Description:
Large area search in imagery for GEOINT targets of interest is a challenging task through means other than visual inspection of pixels. This is largely because it is difficult to identify global mathematical models of the background patterns, textures, shapes, colors, etc. This is particularly true when the goal of the search process is to identify not a specific target of interest, but instead when the image analyst is tasked with searching a region for previously unknown targets of interest. These targets can vary in size, shape, texture, signature, etc., and methods designed to identify a particular signature are less than reliable in these circumstances. As an example of the search problem, if an analyst is considering an image that is 15,000 pixels square, they must inspect 225,000,000 pixels. However, if a scheme can reduce the 225 million pixels to something far more manageable (e.g., 225,000, or 22,500 pixels, factors of 1,000 or 10,000) without missing any new targets, this may be acceptable, providing a much more manageable set of regions requiring visual assessment. This research seeks to develop understanding of the spatial and spectral information in multispectral, high-resolution imagery such that it can be exploited to identify regions that deviate from natural backgrounds and thus present themselves as targets for future analysis.

Our strategy to design tools for assisted image interpretation/analysis has a spectral side and a spatial side. Here we highlight work focused on spatial processing of the image. The major tasks involved on the spatial processing can be grouped under the following three areas: Segmentation, Description and Detection. In our initial attempts at solving the problems of Segmentation and Detection, a key issue that surfaced repeatedly is Image Representation. We found it necessary, to include Image Representation as a major subtask of spatial processing. The goal of the representation was to solve the new challenges, not solved by traditional methods.

Project Status:
The high resolution image brings with it several challenges. It is highly complex with relevant structures occurring at several scales. A single segmentation or image representation may not capture all the information present in the image and thus requiring multi-scale techniques. A framework for Scale-Space Representation was developed to deal with complexity and organization of multi-scale information. Figure 3.20-39 below shows the scale-tree of an image from the WorldView-2 Sensor. The scale-tree reflects the scale-space of the image. At the bottom of tree are nodes corresponding to small structures/objects such as cars and ships. Nodes higher in the tree correspond to bigger structures such as roads and buildings.

The scale tree, made up of image regions, does not directly map into an object tree where each node is a semantic object in the scene. The subject of our current research is to improve the scale tree, in the presence of domain or expert knowledge and probabilistic framework, to more closely represent the semantic object structure in the image.

3.21 Voxelized Approaches to LIDAR Exploitation

Sponsor: Laboratory for Advanced Spectral Sensing

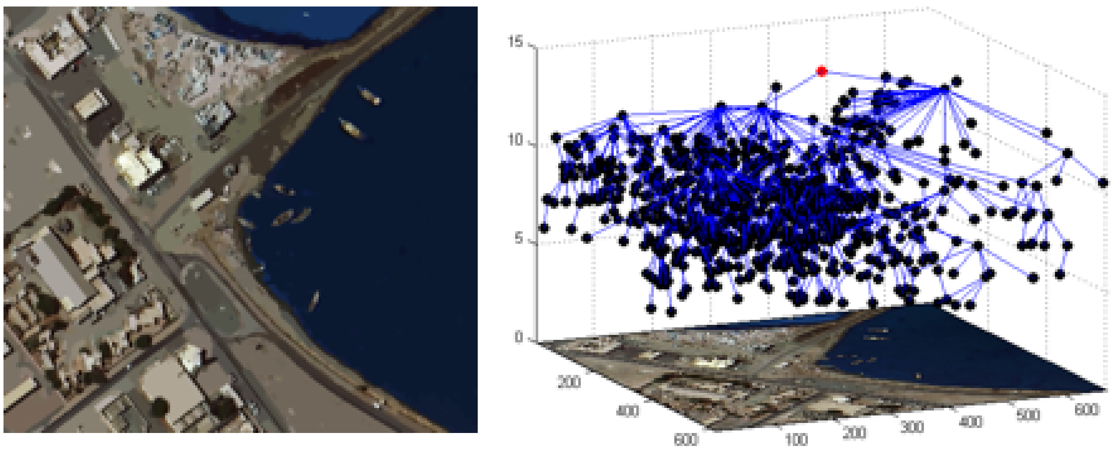


Figure 3.20-39: Scale tree representation of a multispectral image showing the decomposition of objects within the scene based on varying size.

Principal Investigator(s): Dr. David Messinger

Research Team: Shea Hagstrom (CIS - Ph.D.)

Project Description:

The introduction of LIDAR is one of the most important advances to the remote sensing field because of the additional information it can provide compared to passive imaging systems. LIDAR's main advantage over other modalities is that it can natively map coordinates in 3-dimensional space and provide information about surface structure and properties with great detail. In situations where the geometrical structure of a scene is of prime importance this ability is invaluable, especially since many modern airborne systems are capable of quickly covering large areas while achieving sub-meter resolution. In order to fully exploit the geometric information available in LIDAR data it is important to consider the effects of the technique used when reconstructing a scene model from raw point clouds. Nearly all traditional methods rely on the use of a digital surface model to build a representation of the scene area. However, in cases where there is significant above-ground complexity and overlap these simple surface methods can produce incorrect or erratic results. For this reason we use a voxel representation which uses a regular volumetric grid rather than surfaces. This voxelized approach means we can correctly handle overlapping objects and statistically generate properties on a per-voxel basis.

This ability of a voxel map to handle the complex natural and man-made object geometry present in urban areas makes this approach ideally suited to these locations. One application where this type of representation proves particularly useful is in calculating a line-of-sight map, or viewshed, showing what is visible from an arbitrary point within the scene. Current commercial software implementations of line-of-sight mapping rely on surface representations of a scene and can lead to erroneous results, especially if small above-ground details are important and can be resolved by the LIDAR instrument. Using a voxel map means we can correctly handle the effects of objects on line-of-sight, and use any additional knowledge gained in the construction to improve our results. The past year of work focused on application of these voxel approaches to a complex urban environment such as downtown Rochester, NY.

Project Status:

Under this project we have developed a voxelized approach to LIDAR processing that uses not only the point cloud information from a LIDAR system, but also the position and orientation data from the LIDAR at the time of collection. With this information, we can estimate the transmission of each voxel in the space based on knowledge of whether or not the LIDAR beam actually traversed the voxel. Consequently, we can not only identify the solid surfaces in the scene, but also those portions of the scene not sampled by the LIDAR. Figure 3.21-40 shows the effect of voxelization on a portion of the downtown Rochester scene. Here, solid surfaces are shown in gray while unsampled voxels are shown in orange.

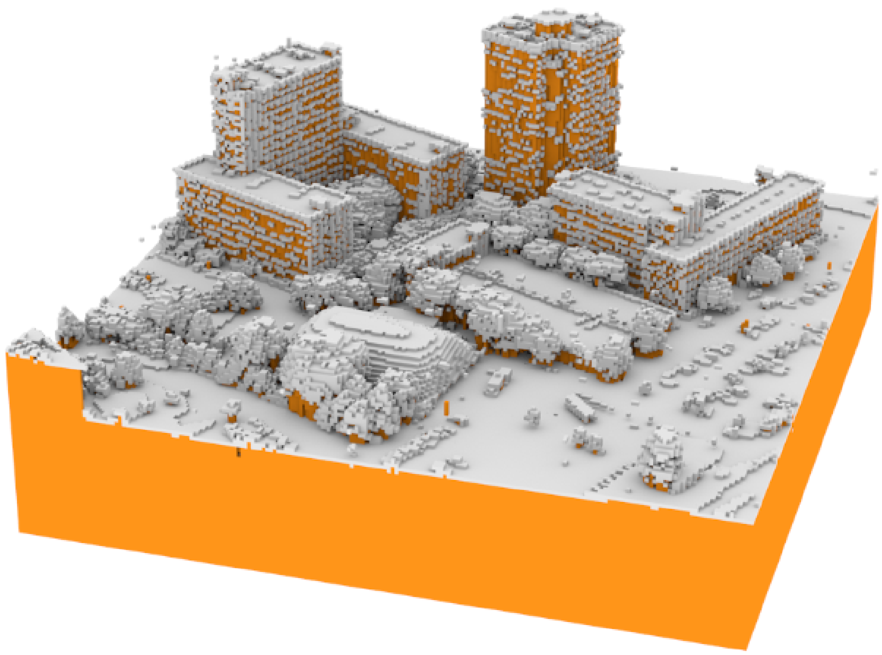


Figure 3.21-40: Voxel map of a portion of the downtown Rochester scene. Voxels are $1 \times 1 \times 1$ m in size. Solid surfaces are shown in gray while unsampled voxels are shown in orange.

Using this information we can then perform a line of sight analysis that includes uncertainty estimates based on whether voxels in the line of sight under consideration have been sufficiently sampled. Those portions not sampled are labels as having "possible" line of sight - a distinction important in many applications and not possible in the tradition facetized surface approaches to line of sight estimation. Figure 3.21-41 shows the resulting line of sight map of the downtown Rochester area for a specific point. In this case, the source point is shown as the red dot at the top of a building in the center of the image. Known regions within sight of that spot are shown in green while uncertain areas, based on knowledge of unsampled voxels in the area, are shown in yellow. This additional information is an advancement on the traditional approaches for this problem.

3.22 Remote Sensing for Archeological Studies of Oaxaca, Mexico

Sponsor: NASA ROSES

Principal Investigator(s): Dr. David Messinger, Dr. Bill Middleton (RIT COLA)

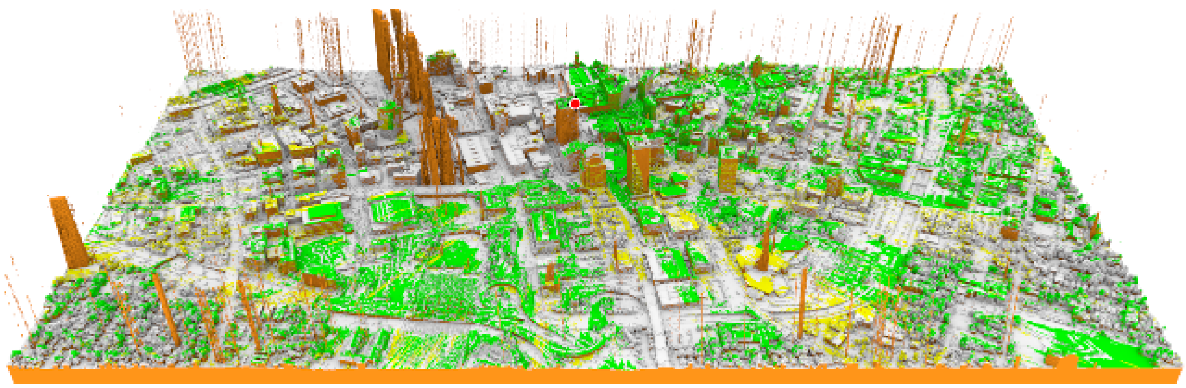


Figure 3.21-41: Line of sight map for the downtown Rochester area based on the voxel map created. Source point is red dot in center. Confident line of sight regions are denoted by green; uncertain regions are shown in yellow. Unsampled regions of the voxel map are shown in orange.

Research Team: Kelly Canham (CIS - Ph.D.)

Project Description:
A recent study of the ancient Zapotec statehood from Oaxaca, Mexico, focuses on how the people impacted their environment and how the environment impacted the state. Determining the different materials and land-uses of the region is a critical step of this research. Spectral unmixing has been performed on hyperspectral Hyperion imagery of Oaxaca to help automatically identify the number of different materials and the spectral proles of the different materials. All this analysis, however, does not identify what these materials are. In December 2011 ground truth data was collected to help identify some of the spectrally unmixed materials. Ground truth data was collected from three valleys in Oaxaca: Tlacolula, Yanhuitlan, and Ycuitla Valleys. Tlacolula is one of the valleys that forms the Central Oaxaca Valley, where the present day state capital city (Oaxaca Cuidad de Juarez) is located. Both Yanhuitlan and Ycuitla are part of the larger Nochixtlan Valley and are found approximately 70 km north-west of Oaxaca Cuidad de Juarez. The social and political environment of Mexico and the custom regulations between Mexico and the USA were all challenges that impacted the outcome of this eld campaign. However, eld notes, digital photos, and sample materials were collected from 56 points of interest within the three valleys. The reectance spectra of the collected material samples were later measured in a laboratory using an Analytical Spectral Device Field-Spec Pro and constant light source. The results of the ground-truth data were compiled into Geographical Information System (GIS) truth maps and a material spectral library.

Project Status:
Spectral unmixing methods identify and separate the constituent materials (or endmembers, EMs) within a single pixel. EM spectra and EM abundance maps are the results of spectral unmixing. Most spectral unmixing is based on a linear mixture model3 where the pixel spectrum is approximated as a linear combination of the different EMs weighted by their associated material abundances per pixel.

However, without a spectral library or truth data that associates the EM spectra to known materials it is not possible to convert the unmixed EM abundance maps into material abundance maps. Generally, EMs are considered to be the pure materials in the imagery because the linear mixture model identies the EMs as the corners of the convex hull and all other pixels which fall within the hull corners are a combination of the EMs. The purity of the materials within a single pixel and the different imaging variations make it difcult to accurately relate the materials found on the ground to the mathematical EMs derived without ground-truth information. The material purity is impacted by the size of the pixel footprint in relation to the size of the materials being identied.

The ground-truth eld campaign occurred on December 1-15, 2011, traveling to three valleys in Oaxaca, Mexico, to collect in-eld material spectral proles. The eld campaign was planned for December to coinicide with the dry season in Oaxaca providing a lower chance of clouds obscuring the ground. The ground-truth data collected in Oaxaca, Mexico, consisted of eld notes and diagrams, digital pictures of the location, GPS locations, and when possible material samples (see Figures 3.22-42 & 3.22-43). The eld notes, digital photos, and GPS locations were compiled into a single GIS map with high-spatial resolution (HSR) WorldView-2 or Quickbird imagery so that the entire region of a single common material or feature could be outlined. The social and political environment of Mexico prevented large numbers and amounts of material samples from being collected and shipped back to the Rochester Institute of Technology for laboratory testing. The samples that were collected mainly consisted of soils and senescent vegetation collected on public lands.

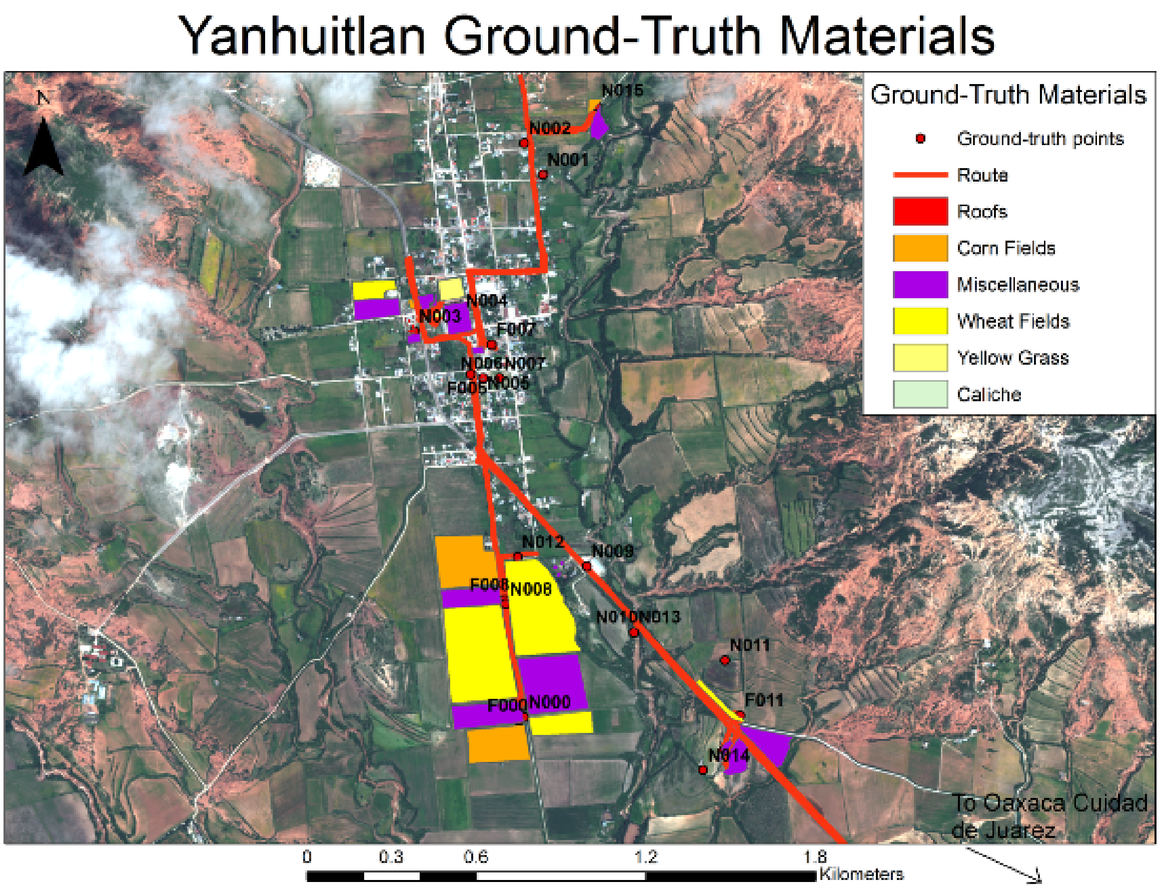


Figure 3.22-42: Material ground truth locations in the Yanhuitlan valley, Oaxaca, Mexico.

Ground-truth information for HSI imagery is needed to produce nal material abundance maps. The key step missing in many unmixing algorithms is identifying the relationship of the extracted endmembers to on-the-ground materials which appear in the HSI imagery. Many challenges must be overcome when collecting ground-truth information for HSI imagery. During December 2011, when a eld-campaign was

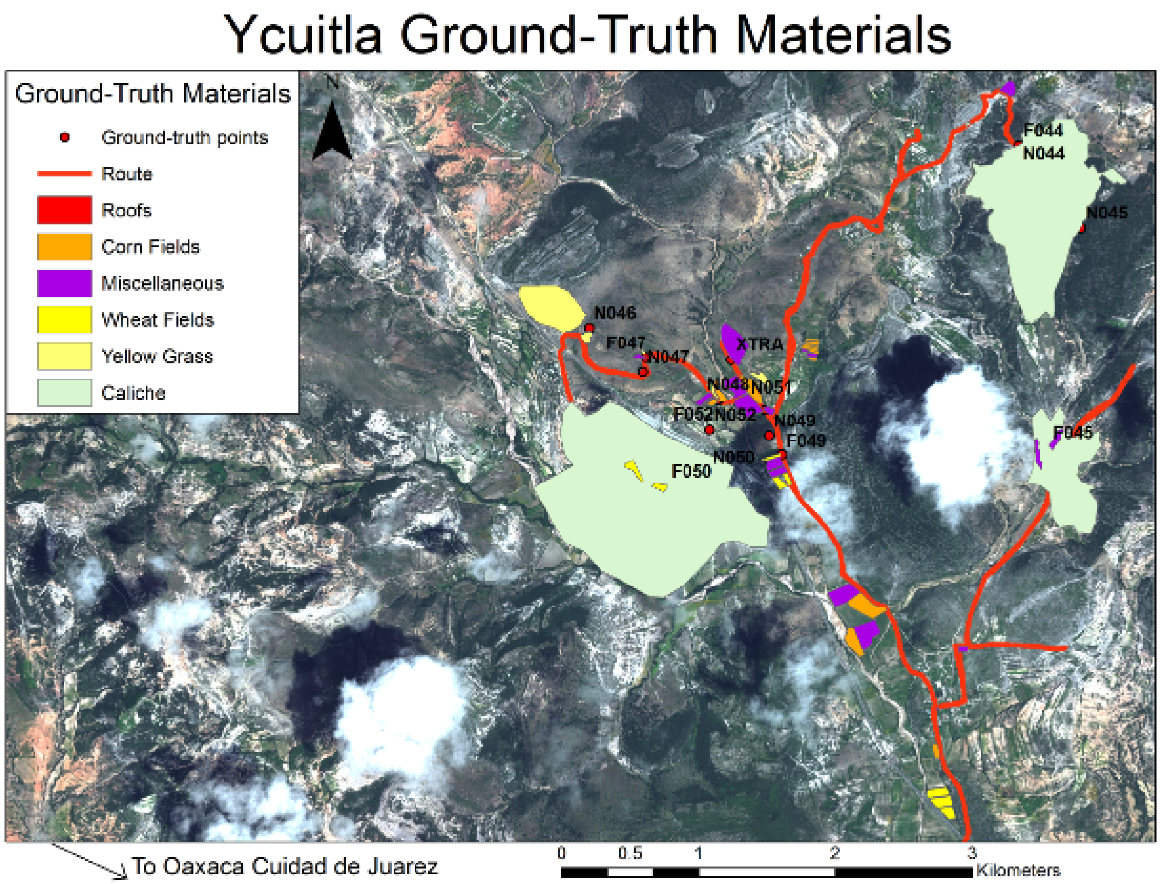


Figure 3.22-43: Material ground truth locations in the Ycuitla valley, Oaxaca, Mexico.

conducted to obtain ground-truth information to aid in Hyperion spectral unmixing of Oaxaca, Mexico. The political and social environments reduced the effectiveness of the trip and customs regulations prevented a spectralradiometer from arriving in Oaxaca resulting in no on-site spectral measurements. Additionally, operations of the satellite bus of the Hyperion sensor prevented an image of one of the three key valleys from being imaged. Therefore, eld notes, GPS locations, digital images, and material samples were collected from three valleys within Oaxaca, Mexico. The material samples collected were shipped back to Rochester Institute of Technology where their spectral reectance was measured and the resulting spectral library and GIS truth-maps have been presented. The resulting spectral library is a sparse collection of materials present in the imagery, but is an initial proof-of-concept which can be used to determine if the spectral unmixing endmembers derived from the Hyperion data can be compared to sample lab measurements in future work.

3.23 Simulation of Urban Night Scenes Based on GIS Data

Sponsor: Sandia National Laboratory

Principal Investigator(s): Dr. Mike Gartley, Dr. David Messinger

Research Team: Joshua Zollweg, Chris DeAngelis

Project Description:
The overall aim of this research was to investigate various workflows sufficient for generating large scale scene models for rendering radiometrically accurate night time imagery. Previous works have achieved adding street lamps and car headlights to virtual scene models via hand placement of each light source and over a limited spatial extent. The intent of the work is to provide both sponsors and fellow researchers with a framework for radiometrically rendering nighttime radiance imagery (given publically available inputs) for sensor design trade studies and algorithm development work.

Project Status:
We have demonstrated use of publically available NASA SRTM terrain data, 30m GSD ground albedo maps derived from LANDSAT-7 spectral bands, and Open Street Map GIS data for generating large scale (up to 100 km x 100 km) scene models that may be rendered in the DIRSIG software model under nighttime conditions. The resulting radiance imagery is oftentimes radiometrically close to nighttime radiance imagery collected most recently by the Day Night Band (DNB) of the VIIRS imager on the NPP satellite. Although a direct spatial correlation between modeled and DNB imagery is not always present due to the variation in the amount of street level information available in the Open Street Map data across various regions of the United States and the rest of the world, we have found an excellent overall statistical (not requiring exact spatial correlation) agreement between modeled and measured nighttime radiance imagery over urban and suburban areas. Future development work will examine how to integrate geometric effects from adjacent objects other than terrain, such as buildings and trees that might improve the fidelity of the modeled results.

3.24 Geometrically Constrained Signature Spaces for Physics-Based Material Detection

Sponsor: Exelis Inc. and National Geospatial-Intelligence Agency (NGA)

Principal Investigator(s): Dr. Emmett Ientilucci

Research Team: Dr. Emmett J. Ientilucci, Dr. Rolando Raqueno, Dr. Peter Bajorski

Project Description:
The goal of this project is to develop new algorithms and methods that combine information from hyperspectral and LIDAR data to better identify objects of interest. The hyperspectral data enables one to better understand the material properties of an object. The LIDAR data enables one to define the dimensions and shape of an object as well as illumination conditions. Spatial LiDAR processing is used, collectively with HSI and a technique of constrained target spaces, to further enhance material detection by mitigating false alarms based on shape rather than spectral character.

Project Status:
We stared off the year by investigating a new methodology to obtain shadow, aspect, slope, and sun angle maps. These were originally computed (unsuccessfully) by hand in IDL. A software package called Quick Terrain Modeler (QTM) was able to perform such tasks. We then focused on how to export files in certain formats, perform some post-processing and then use them appropriately in the target detection GUI. Tests were performed on two data sets, which contained co-registered HSI and LiDAR information, which is crucial to this project. One data set with synthetically generated via DIRSIG. The other was provided

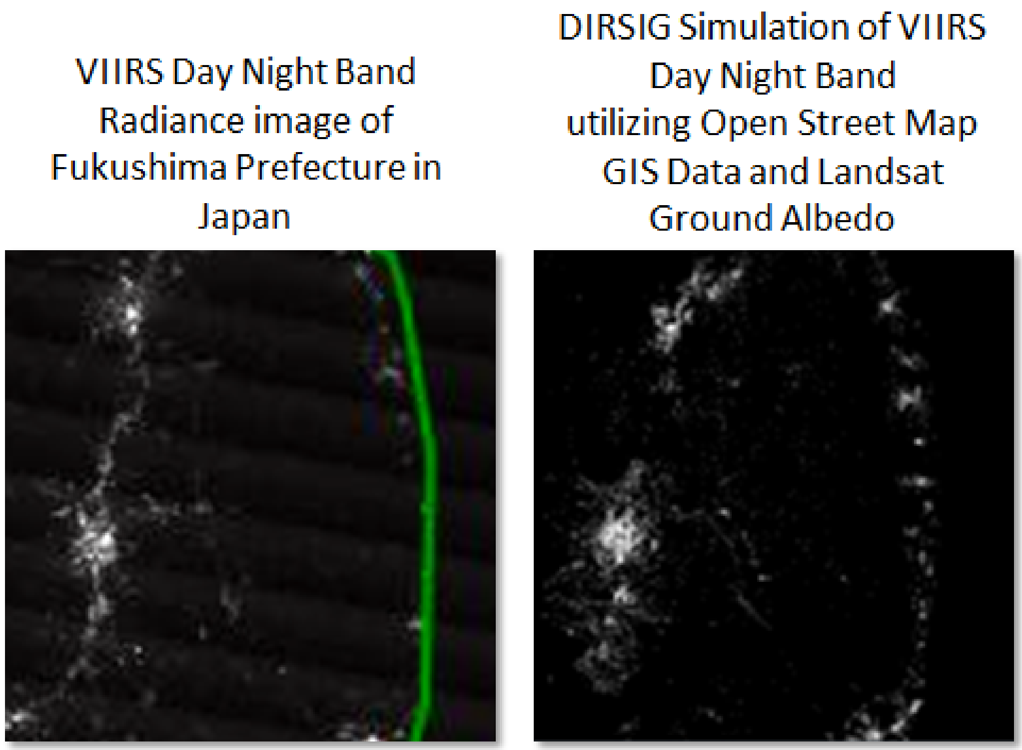


Figure 3.23-44: Simulation of urban night lights in DIRSIG.

by NGA, termed the Gulfport data set. Extensive testing and refinement was performed on both data sets in the generation of the above mentioned maps. We are confident that LiDAR derived maps are now computed correctly and in an efficient manner (see Figure 3.24-45). There was some additional research into the computation of the sky-view or shape factor map. It was found that an ENVI plug in computed sky-view images that were accurate and very fast. John Hopkins University has also followed this model, with the help and assistance of outcomes and suggestions from this research. Target detection was performed on the DIRSIG and Gulfport data sets as well. From the DIRSIG results we found that using a local (i.e., using maps) enabled the detection of vehicles in both full illumination and full shadow. This lead us to implement the algorithms on real data such as the Gulfport scene. Findings here were not as conclusive. All of the targets were found in global mode, regardless of using local mode. This was not exactly the case with the SAM algorithm, however. Here, the local mode helped to find the smallest of brown targets. Additional study will be performed using different targets, for example. Furthermore, there is another LiDAR / HSI data set collected by RIT which contains targets in both full illumination and full shadow that should prove to be very challenging. The target detection GUI will be evaluated against this data set as well.

3.25 3D Model Extraction and Representation

Sponsor: Esri

Principle Investigator(s): Dr. Scott Brown

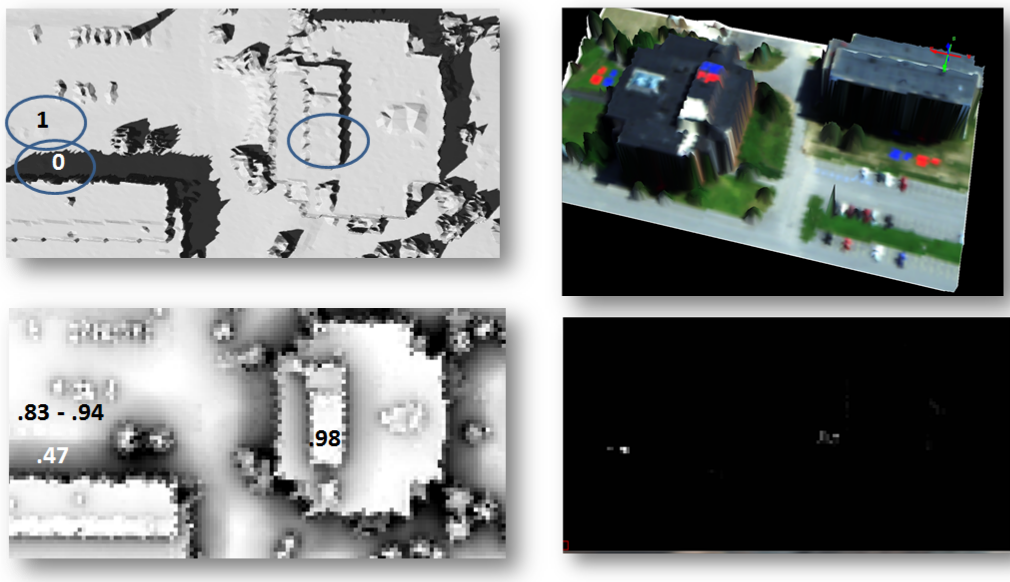


Figure 3.24-45: Processing of LiDAR data to obtain a a spatial estimate of shadow (upper left) and amount of sky-illumination or sky-loading (lower left). Upper right illustrates an RGB image draped over a LiDAR image showing various red and blue target panels, some not seen are in the deep shadow. Lower right illustrates the results of the developed algorithm which is able to locate the targets in shadow.

Research Team: Dr. Carl Salvaggio, Dr. Harvey Rhody, Mike Richardson, Nina Raqueno, Robert Krzaczek, Erin Ontiveros and David Nilosek

Project Description:

Ultimately, the goal of this research area is the creation of physically attributed, 3D models of a site that could be explored, visualized and rendered by multi-model modeling tools like DIRSIG. In operation, the user will jumpstart a site model by injecting a set of multi-model imagery into the RIT image geometry toolbox. This may include panchromatic imagery, multi-spectral imagery (MSI), hyper-spectral imagery (HSI) and/or polarimetric imagery (PI). It may or may not include information about sensor models and platform ephemeris. The toolset will generate a 3D model of the site. The general approach has been to leverage the wealth of image geometry algorithms to create 3D site models from collections of 2D images that are back-ended by physics descriptions. The toolbox of algorithms we are using contain 2D to 2D (image to image), 2D to 3D (image to model) and 3D to 3D (model to model) tools. These tools have been combined in a toolchain to perform relative registration of data, 3D model creation and 2D to 3D model mappings. Most of our work has leveraged the “photo-tourism” techniques developed by Dr. Noah Snavely at the University at Washington. His general approach is called “Structure from Motion” (SfM) and is based using large collections of images of the same site (usually collected by tourist) and identifying registering the images together in a 3D space through the a combination of image feature extraction, feature matching and 3D object space reconstruction. The work at RIT has largely focused on how these approaches can be applied to overhead imagery which is generally characterized by lower spatial resolution and decreased image coverage (fewer images of the same site).

Project Status:

During the last year, the team focused on refinements to a semi-automated Structure From Motion (SfM) workflow to process overhead, remotely sensed imagery. David Nilosek's student research work transitioned onto the extraction of 3D structures (polygons) from dense point clouds.

As another demonstration of the SfM workflow, RIT feed a images collected but the RIT WASP sensor of Haiti after the earthquake event. This was an interesting application because the Haiti data was collected to maximize area coverage (a common mission goal for remote sensing scenarios). As a result, the image-to-image overlap was not high and this overlap is a key requirement for the SfM approach. However, the SfM workflow was found to work surprisingly well on this dataset. The images of the 3D point cloud in Figures 3.25-46 and 3.25-47 highlight the detail in the terrain and man-made structures that were extracted from the imagery. Note the appearance of a radio tower on the top of the hill in the Figure 3.25-47.

Figure 3.25-46: Screenshot of large 3D point cloud generated from images collected by the RIT WASP sensor in Haiti after the earthquake.

Funding for this project ended in June of 2012, and the team was able to summarize several important observations regarding the use of remote sensing imagery with a Structure from Motion workflow. The photo-tourism application typically employs a large number of images of the same object of interest (for example, the Eifel Tower, Statue of Liberty, etc.) and the 3D recreation of the object is the desired outcome. In contrast, a common remote sensing application is to map a large area (with very little duplication of the same object in the collected images) and the desired outcome is to reconstruct every object within the collected area. However, the Haiti collection showed that a minimal amount of image-to-image overlap could help produce very detailed 3D point clouds.

3.26 DIRSIG Infrastructure

Sponsor: Internally Funded

Principle Investigator(s): Dr. Scott Brown

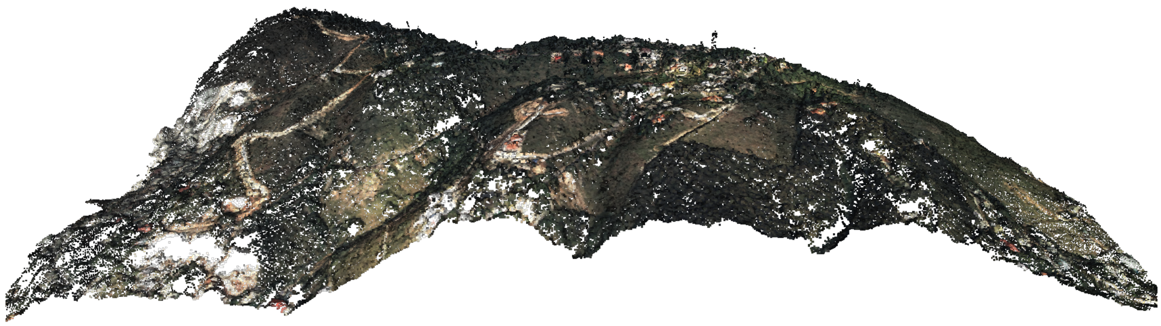


Figure 3.25-47: Screenshot of small region of the 3D point cloud generated from images collected by the RIT WASP sensor in Haiti after the earthquake.

Research Team: Dr. Adam Goodenough and Dr. Mike Gartley

Project Description:
In addition to the sponsored research projects that address the enhancement of the DIRSIG model, RIT has been slowly increasing the amount of internally funded staff time that is spent working on infra-structural DIRSIG development. The goal of this ongoing project is the continued improvement of the DIRSIG user experience. Specifically, to improve the utility of the tool and integration of the tool with other engineering tools commonly used alongside DIRSIG. We internally fund a great deal of the strategic software development that allows us to accomplish research already in-house and compete for new research opportunities. One of the fundamental funding streams for DIRSIG core development has been the DIRSIG Training Courses, which was offered on four (4) different occasions during the last calendar year, including off-site sessions in Virginia and Maryland.

Project Status:
During most of the past year, the development team focused on Release 4.4.2 and 4.4.3. The important milestones of that effort was the continued improvements to the graphical user interface (GUI) in an effort to make the GUI an invaluable tool to new and old users. The following list highlights the new features introduced in the 4.4 series of releases.

- Optimizations for LIDAR simulations that improved execution times by 20x.
- User interface access to the "adaptive sampling" algorithm that improves sub-pixel sampling.
- User interface access to the "data-driven focal plane" mechanism introduced under the Landsat Data Continuity Mission (LDCM) project in 2010-2011.

- The creation of twelve (12) new self-contained demonstrations ranging from various LIDAR effects to modeling Bayer Pattern focal planes.
- Improvements to the experimental and evolving RADAR modality.
- The start of a new documentation effort that will replace the outdated documentation produced nearly a decade ago.

During the next year, the development team will continue to provide the user community with improved versions of the DIRSIG model with an increased focus on integration into the modeling workflows used by the user community. This upcoming year will also see more enhancements to the user interface, improved documentation and outreach to educate the user community and the expansion of off-site training sessions to make training more accessible.

The final major effort during the past year was that we have started to invest our own resources into the design and prototyping of the next generation of DIRSIG (DIRSIG5). Adam Goodenough is currently spear-heading this effort, which represents another major shift in architecture, moving to a more modular design to support faster, isolated turnaround of new or improved features and allowing plug-in functionality. We are also vigorously addressing simulation speed - from the load time of scene properties and geometry, to the computation of radiometry - exploiting hardware (GPU, multiple cores, etc.) wherever possible. We also recognize that the field of computer graphics has advanced significantly since the early days of DIRSIG when most of what is now considered to be fundamental technique had to be homegrown. In addition to having these ideas influence our design and tools, we are also attempting to use optimized and mature libraries to fulfill fundamental needs in the code (when licenses allow) - giving us more time to focus on our fundamental goal of being a premier remote sensing simulation tool. The architecture design is goal-oriented and we are letting it evolve as we attempt to find the best way to meet the following set of goals:

- Stable core with fewer major revision cycles
- Modular non-core design for platform/scene development and external plug-ins
- Shorter development cycles for new and improved, modular functionality
- Faster geometry intersections and radiometry solver solutions with GPU exploitation
- Better handling of large data files (property maps, DEMs, geometry/image files)
- Improved modeling of multiple, independent instruments and platforms
- Top-level scheduling of complex tasking and temporal interactions
- Optimized, universal matrix math library
- Top level, scriptable data model for all simulation component properties
- Improved extensibility of the GUI for advanced simulation interfaces
- Geocentric atmosphere, scene, and space models.
- Support for multiple scenes, atmospheric objects, and a background planet DEM

3.27 Large Area Polarimetric Scene Simulation and Phenomenology

Sponsor: Sandia National Laboratory

Principal Investigator(s): Dr. Michael Gartley

Research Team: Erin Ontiveros

Project Description:
This work was a continuation of previous Large Area Polarimetric Scene Generation research, with the most recent focus being on generating tools for scene generation and verifying simulated results against publically available real datasets.

Project Status:
During this phase of the project, we developed IDL based tools for utilizing the POLDER-3 BRDF database (developed and provided by the Centre National d'Etudes Spatiales, the French space agency) to attribute a SRTM derived terrain geometry with appropriate spectral and polarimetric reflectance properties for large scale simulations. More specifically, the monthly average class specific values from the BRDF database were utilized to generate a variety of radiance image simulations spanning multiple seasons throughout the year. The figure above demonstrates a RGB, false color IR and a total radiance image at 865nm comparison between DIRSIG modeled images and POLDER-3 acquired images over an approximately 125 x 100 km region of the eastern coast of the Japan mainland. These image simulations utilized a total of 3 GLC2000 land classes, namely Urban, Cultivated and Mixed Forest, to represent the terrain features. Future work is likely to include development of a workflow to introduce finer scale geometry beyond the simple LANDSAT-derived reflectance mapped onto a SRTM derived terrain, such as city buildings and forests of geometrically accurate trees.

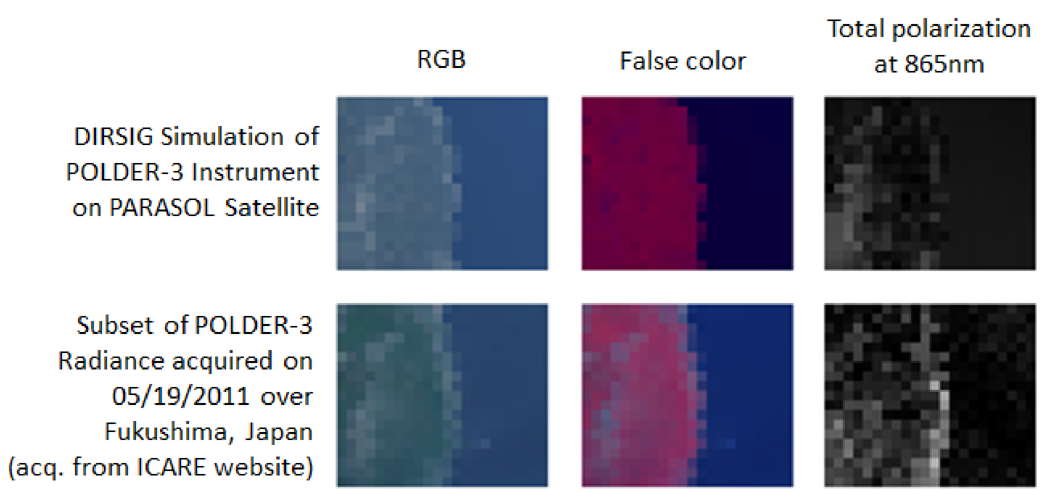


Figure 3.27-48: Large area polarimetric scene simulation in DIRSIG.

4 Publications During This Period

[1] J. Wu, J. A. van Aardt, J. McGlinchy, and G. P. Asner, "A robust signal preprocessing chain for small-footprint waveform lidar," *IEEE Transactions on Geoscience and Remote Sensing* **50**, pp. 3242–3255, August 2012.

[2] J. A. Albano, D. W. Messinger, and S. R. Rotman, "Commute time distance transformation applied to spectral imagery and its utilization in material clustering," *Optical Engineering* **51**, July 2012.

[3] A. Schlamm, D. W. Messinger, and B. Basener, "Interest segmentation of large area spectral imagery for analyst assistance," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **5**, April 2012.

[4] L. Meng and J. P. Kerekes, "Object tracking using high resolution satellite imagery," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **5**, pp. 146–152, February 2012.

[5] A. Vodacek, "Linking year-to-year cladophora variability in lake ontario to the temperature contrast between nearshore and offshore waters during the spring," *Journal of Great Lakes Research* **Available Online**(doi: 10.1016/j.jglr.2012.02.013), 2012.

[6] D. W. Messinger, A. Ziemann, B. Basener, and A. Schlamm, "Metrics of spectral image complexity with application to large area search," *Optical Engineering* **51**(3), 2012.

[7] D. Sarrazin, J. A. van Aardt, G. P. Asner, J. McGlinchy, D. W. Messinger, and J. Wu, "Fusing small-footprint waveform lidar and hyperspectral data for canopy-level species classification and herbaceous biomass modeling in savanna ecosystems," *Canadian Journal of Remote Sensing* **37**, pp. 653–665, December 2011.

[8] K. Canham, A. Schlamm, A. Ziemann, B. Basener, and D. W. Messinger, "Spatially adaptive hyperspectral endmember selection and spectral unmixing," *IEEE Transactions on Geoscience and Remote Sensing* **49**, November 2011.

[9] S. S. Kumar, D. P. Roy, L. Boschetti, and R. L. Kremens, "Exploiting the power law distribution properties of satellite fire radiative power retrievals: A method to estimate fire radiative energy and biomass burned from sparse satellite observations," *Journal of Geophysical Research* **116**, October 2011.

[10] J. A. van Aardt, D. McKeown, J. W. Faulring, N. G. Raqueno, M. V. Casterline, C. Renschler, R. Eguchi, D. W. Messinger, R. S. Krzaczek, S. Cavillia, J. Antalovich, N. Philips, B. D. Bartlett, C. Salvaggio, E. M. Ontiveros, and S. Gill, "Geospatial disaster response during the haiti earthquake: A case study spanning airborne deployment, data collection, transfer, processing, and dissemination," *Photogrammetric Engineering and Remote Sensing* **77**, pp. 943–952, September 2011.

[11] M. T. Gebreslasie, F. Ahmed, and J. A. van Aardt, "Extracting structural attributes from ikonos imagery for eucalyptus plantation forests in kwazulu-natal, south africa, using image texture analysis and artificial neural networks," *International Journal of Remote Sensing* **DOI:10.1080/01431161**, pp. 1–25, September 2011.

[12] B. Chen, A. Vodacek, and N. D. Cahill, "Novel spectral similarity measure for high resolution urban scene," in *Proceedings of 2012 IEEE International Geoscience & Remote Sensing Symposium, 2012 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, IEEE, (Munich, Bavaria, Germany), July 2012.

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