R·I·T

DIRS
Digital Imaging and
Remote Sensing Lab

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

Annual Report for the Academic Year 2012-2013

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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Chester F. Carlson
CENTER for IMAGING SCIENCE

Contents

List of Figures

1 Introduction

As we look back on another year in the Digital Imaging and Remote Sensing Laboratory, 2012-2013 was a year of great accomplishment and change. The DIRS laboratory continues to be strong and healthy, with 9 full time faculty members and 16 research and support staff. Additionally, and most importantly, we are supporting over 40 students at the BS, MS, and Ph.D. levels pursuing research in remote sensing. Even in these challenging funding times the laboratory continues to thrive and succeed at developing students for rewarding careers while pushing the edge of the state of the art in remote sensing research.

A major milestone for the global remote sensing community was achieved this past January with the launch of the Landsat Data Continuity Mission, renamed Landsat 8 on commencement of operations. The DIRS laboratory played a major role in the development of this new sensor. Over the past several years we have developed a high fidelity DIRSIG model of the LDCM system from design through construction. The simulation was used to assess the capability of the sensor to achieve its science mission goals, as well as to simulate the data stream coming off the sensor. This second activity allowed NASA and USGS scientists to develop, test, and evaluate the algorithms required to process this new sensor data into science products for the remote sensing community. This activity culminated in the launch of the satellite, at which there were several DIRS members and alumni present.

Another major activity of the group was the planning and execution of the SHARE 2012 data collection campaign. This campaign (described below) was aimed at producing a well ground-truthed, multimodal data set for use by researchers across many application areas. In the end we achieved this goal having 4 aircraft with 8 different imaging sensors and three different imaging satellite systems collect data over target sites in the Rochester area. On the ground were over 50 people from the lab and several other organizations, conducting experiments involving over 200 ground targets and associated measurements of them. The data were then collected, collated, and set up for dissemination to the remote sensing community via a web portal. We hope this and other future experiments can spur on new development and advances in the remote sensing community and we will continue to play the role of data providers as we can.

A major change will come to the lab in 2013. Dr. John Schott, the Frederick & Anna B. Wiedman Professor of Imaging Science and the founding faculty member of the DIRS lab announced that while he wasn't retiring, he would be stepping down from his Chaired position and continuing on at a lower level of effort as a Research Professor. The department has conducted a search to fill this position and we hope that our new faculty member will be a great addition to our group. We certainly do not expect John's presence to diminish significantly as we make this transition - he's already won several multiyear research programs! Finally, as a recognition of John's contributions to the field of Imaging Science he was inducted into the RIT Innovation Hall of Fame this past year, another well-deserved honor.

As always, we thank the RIT administration for their support. 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.

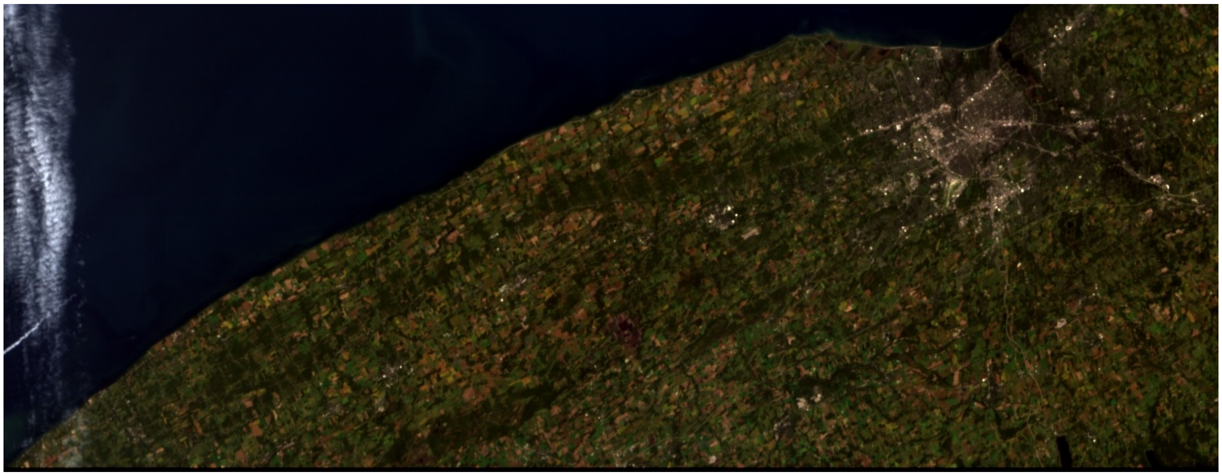


Figure 2.0-1: Image of the Rochester area collected by the HICO sensor on board the International Space Station during the SHARE 2012 collect.

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, 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, 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
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, 2013:

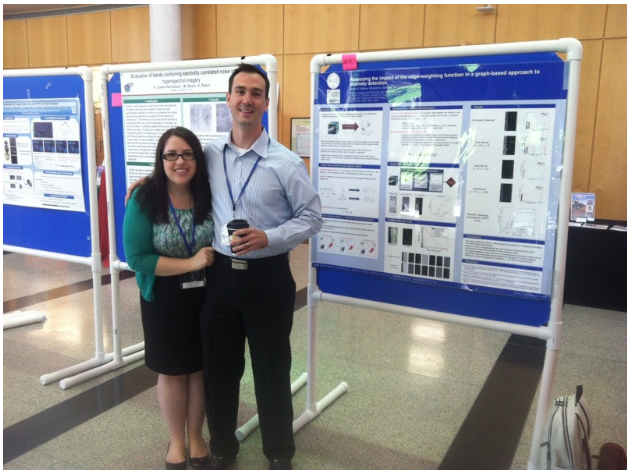


Figure 2.1-2: DIRS Students present at the 2013 IEEE WHISPERS Conference.

BS (8)

Brittany Ambeau
Edward Amsden
Colin Axel
Dan Goldberg
Michal Kucer
Chris Lapszynski
Jessica Maben
Michael Rodgers

MS (12)

Maria Busuioceanu
Bo Ding
AnneMarie Giannandrea
Michael Harris
James Letendre
Jie Zhang
Ming Zhang
Tingfang Zhang
Greg Fertig (USAF)
Colin Fink (USAF)
Christian Lewis (USAF)
Jordyn Stoddard (USAF)

Figure 2.1-3: Launch of the Landsat Data Continuity Mission (LDCM).

Ph.D. (25)

Jamie Albano
Bikash Basnet
Madhurima Bandyopadhyay
Kelly Canham
Bin Chen
Monica Cook
Leidy Dorado-Muñoz
Shea Hagstrom
David Kelbe
Lei Fan
Sanjit Maitra
Troy McKay
David Nilosek
Paul Romanczyk
Katie Salvaggio
Jiangqin Sun
Shaohui Sun
Weihua Sun
Burak Ushkent
William Wu
Jiashu Zhang
Amanda Ziemann
Tyler Carson (USAF)
Rey Jan Garma (USAF)
Oesa Weaver (USAF)

2.2 Theses Defended in Past Year

- Maria Busiouceanou, M.S.
- Cara Perkins, M.S.
- Holly Zelnio, M.S.
- Jie Zhang, M.S.
- Tingfang Zhang, M.S.
- Kelly Canham, Ph.D.
- Jared Herweg, Ph.D.
- Lingfei Ming, Ph.D.
- Sarah Paul, Ph.D.
- Jason Smith, Ph.D.
- William Wu, Ph.D.

Figure 2.2-4: DIRS faculty, staff, and alumni at the launch of LDCM.

3 Research Project Summaries

3.1 DIRSIG Radar Simulation

Principal Investigator: Dr. Michael Gartley
Sponsor: Northrup Grumman Corporation
Research Team: Dr. Adam Goodenough, Dr. Scott Brown

Project Description:

The aim of this research was to incrementally improve the fidelity of the current RADAR simulation capability within the DIRSIG software model. The desired improvements focused primarily on fundamental radiometric improvements and verification for both incoherent and coherent scattering target and background objects. Additionally, the project identified a need for mitigating an issue related to Monte Carlo sampling noise affecting downstream image quality.

Project Status:

Our research team was able to implement a series of model improvements which pushed its capability forward significantly by validation of coherent scattering from simple reflector shapes (flat plate, dihedral, and trihedral) as well as incoherent scattering from extended background materials. This model improvement has not yet been verified for the quad-pol version of the model, plans are to do so in any potential future development work. Additionally, our team also implemented a fundamental change in how the model operates, changing to a two-pass approach in order to mitigate un-wanted sidelobes in the azimuth direction due to Monte Carlo shot noise of the simulation. The first pass transmits photons from the RADAR antenna onto the scene, while the second pass collects the photons and calculates scattering magnitudes based on first principles radiometry versus using the Monte Carlo accumulation of radiometric magnitudes.

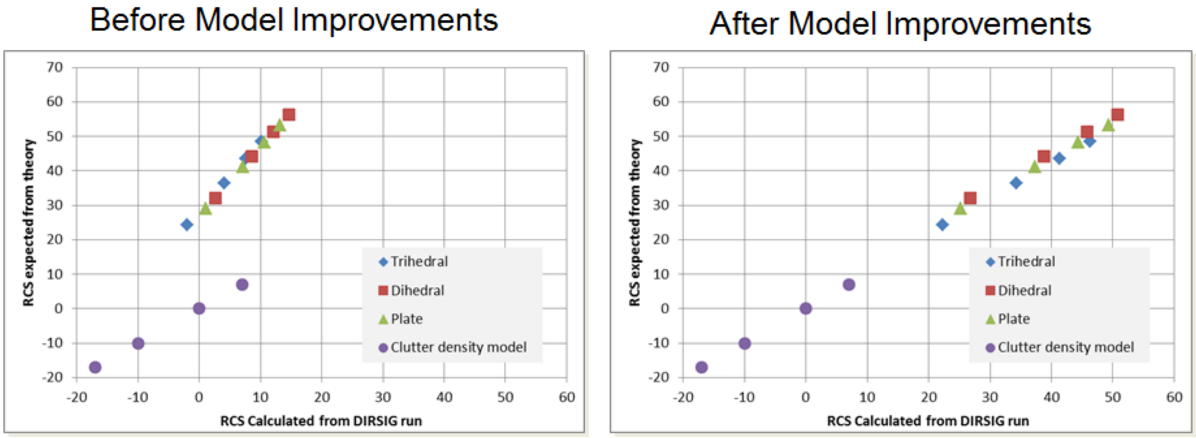


Figure 3.1-5: Two plots showing RADAR cross section values versus values expected from first principles equations before and after model improvements facilitated by this research project.

3.2 Polarimetric Image Modeling

Principal Investigator: Dr. Michael Gartley
Sponsor: Sandia National Laboratories
Research Team: Josh Zollweg (CIS-MS)

Project Description:
The aim of this research was to continue from the previous years research to expand upon our DIRSIG modeling capability for generating radiometric imagery of large scale polarimetric scenes. More specifically we aimed to incorporate seasonal changes in background clutter and their effect on the resulting polarization signatures.

Project Status:
Our team leveraged the existing polarimetric BRDF database produced and maintained by the French Space Agency, Centre National d'Etudes Spatiales (CNES), which is based on measurements from various versions of the POLDER earth observing satellite. Our team built a series of IDL based scripts to translate the polarimetric BRDF database descriptions into a format supported by the DIRSIG model. The resulting simulations were simple in nature (primarily texture mapped terrains with about a half dozen material classes) , but an important step forward in large scale scene simulation including polarization effects.

Figure 3.2-6: Example of the seasonal variation of polarimetric BRDF for two different land classes over the course of a full annual cycle derived from the POLDER BRDF database and rendered in DIRSIG.

3.3 Submerged Object Phenomenology in the Marine Environment

Principal Investigator: Dr. Aaron Gerace
Sponsor: Goodrich Aerospace
Research Team: Mike Richardson and Don Mckeown

Project Description:
This project provided support to the Goodrich Aerospace Corporation to investigate the phenomenology surrounding submerged targets in a marine environment. Specifically, a field experiment was conducted in this effort where several targets were submerged at various depths in ocean water and the phenomenology observed. RIT lead the planning and execution of the field experiment on the ground and was involved in the analysis of the airborne image data to identify interesting phenomena. Figure XX shows an example of an object submerged in water and the apparent phenomenology (e.g. glint) associated with identifying these objects.

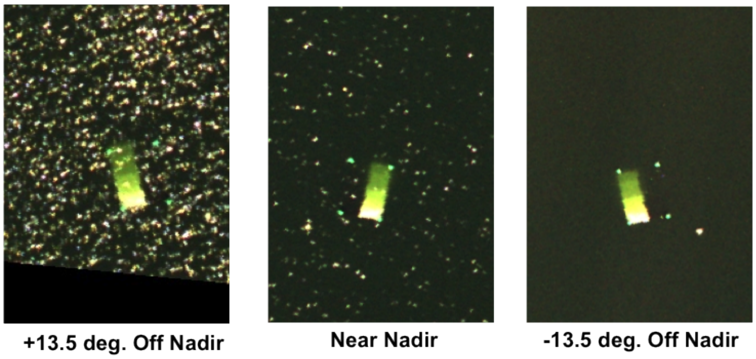


Figure 3.3-7: Sample imagery of a submerged target in a marine environment showing the phenomenology (e.g. glint) associated with the detection of these objects.

Project Status:
Although this project has ended, it has lead to ongoing research in the area of submerged object detection. Future efforts are focused on using the DIRSIG model to develop a glint avoidance sensor-tasking tool and to investigate, and potentially enhance, existing glint removal algorithms.

3.4 Geometrically Constrained Signature Spaces for Physics-Based Material Detection

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

Principal Investigator: Dr. Emmett J. Ientilucci
Research Team: Dr. Emmett J. Ientilucci, Dr. Rolando Raqueño

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 loading conditions. Spatial LiDAR processing is used, collectively with HSI and a technique of constrained target spaces, to further enhance material detection by accounting for illumination effects across a scene (i.e, locating materials in both the open and shadowed areas simultaneously).

Project Status:
To date an interactive GUI has been designed as a plug-in to the ENVI software. The plug-in has the ability to ingest both HSI and LiDAR data. It facetizes the LiDAR point cloud data and creates shadow, in-direct sky-loading, and surface angle to the sun maps. MODTRAN automatically runs to compute the radiation transfer of the signature through the atmosphere up to the sensor. One of many detection schemes is selected in the GUI which then produces a detection map result similar to that shown in Figure 3.4-8.

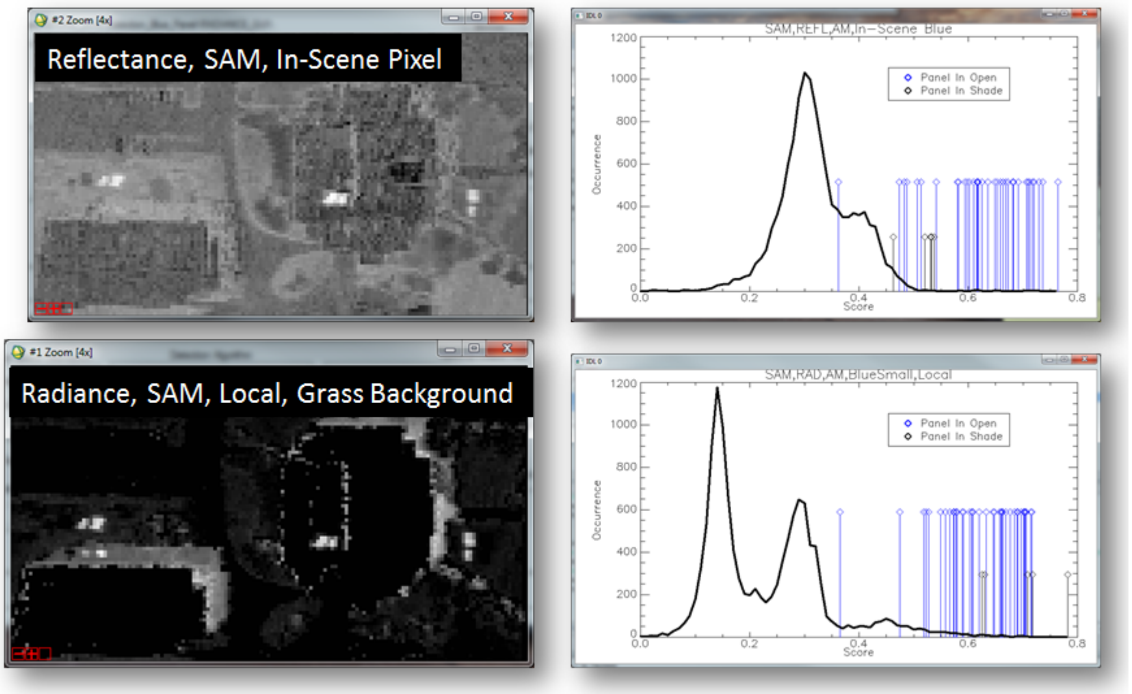


Figure 3.4-8: Detection results using SAM on both reflectance and (local) radiance data. The local radiance result (use LiDAR processed maps, is able to locate the blue panels in shadow.

3.5 Improved Detection Using Multiple Satellite-Based Images

Sponsor: RITRE, Corp.
Principal Investigator: Dr. Emmett J. Ientilucci Research Team: Dr. Emmett J. Ientilucci

Project Description:
The goal of this effort is to process space based imagery (HSI Hyperion and multi-spectral Landsat and Aster data) to produce end products like target detection.

Project Status:
Thirteen HSI Hyperion, 24 Aster and 17 Landsat flight lines were processed. This involved the atmospheric compensation of all flight lines using the physics based Fast line of sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) code found in ENVI. Target detection was performed in ENVI, using the THOR workflow, on all the cubes searching for 11 unique minerals. The final output was KML and Shape files for each of the 11 minerals for each of the cubes. All results and data were placed on a CIS FTP server for download by the customer, to be processed further in a GIS environment. Figure 3.5-9(a) shows the result of compensating both the Landsat and Hyperion images illustrating a typical vegetation pixel. Figure 3.5-9(c) shows an example of minerals found using four target detection schemes and default threshold settings in ENVI.

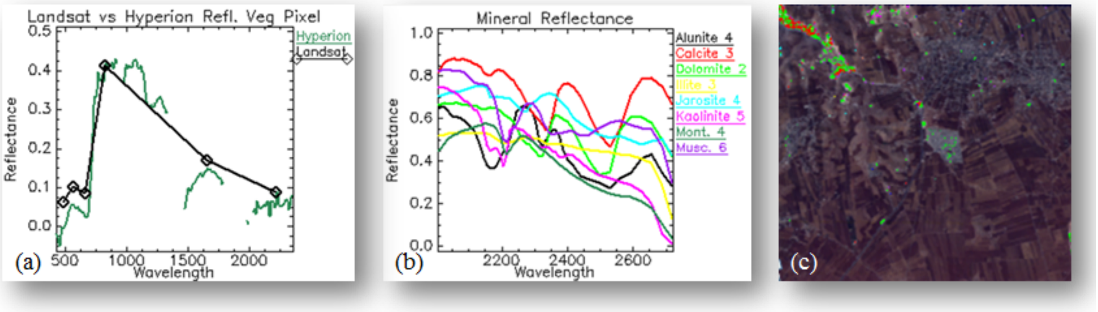


Figure 3.5-9: (a) Compensated vegetation pixel from radiance images of Landsat and Hyperion, (b) minerals uses in the target detection scheme and, (c) results of found minerals over plotted onto a Hyperion image.

3.6 Oblique Hyperspectral Imaging BRDF Study

Sponsor: Mitre Corporation
Principal Investigator: Dr. Emmett J. Ientilucci
Research Team: Dr. Emmett J. Ientilucci

Project Description:
This project will focus on understanding and modeling the BRDF phenomenology associated with oblique aerial collections. Analysis will include variation of source-target-sensor geometries typically assumed to be constant in nadir viewing situations. Additionally, parameters such as atmospheric transmission, ground sample distance and bidirectional reflectance distribution functions (BRDF) will be studied to see what impact BRDF and oblique viewing has on applications such as target detection, since little research has been done in this area. As a result, this project aims to determine and quantify the limiting factors of current nadir-looking processing chains when applied to off nadir collection scenarios

Project Status:
To date, a scene simulation has been established. This includes determining such parameters as sensor altitude, location on Earth, elevation, data, time of day, atmospherics and visibility, material and sensor specifications. The combinatorics for the trade study has also been established. The Forecasting and Analysis of Spectroradiometric System Performance (FASSP) model will be used to predict target detection performance both in nadir and oblique viewing geometries. BRDF simulations of various materials can be seen in Figure 3.6-10, using the Nonconventional Exploitation Factors Data System (NEFDS) database coupled with the Beard-Maxwell model. These will be used as input to the FASSP model.

3.7 Multimodal Image Generation and Exploitation

Sponsor: Raytheon Corporation
Principal Investigator: Dr. John Kerekes
Research Team: Kevin Bloechl (CIS - MS), Chris De Angelis, Dr. Michael Gartley, and Dr. Scott Brown

Project Description:
This project is a continuation of collaborative activity with our sponsor at Raytheon aimed at evaluating and improving multimodal image simulation using the DIRSIG tool, and developing analysis techniques to

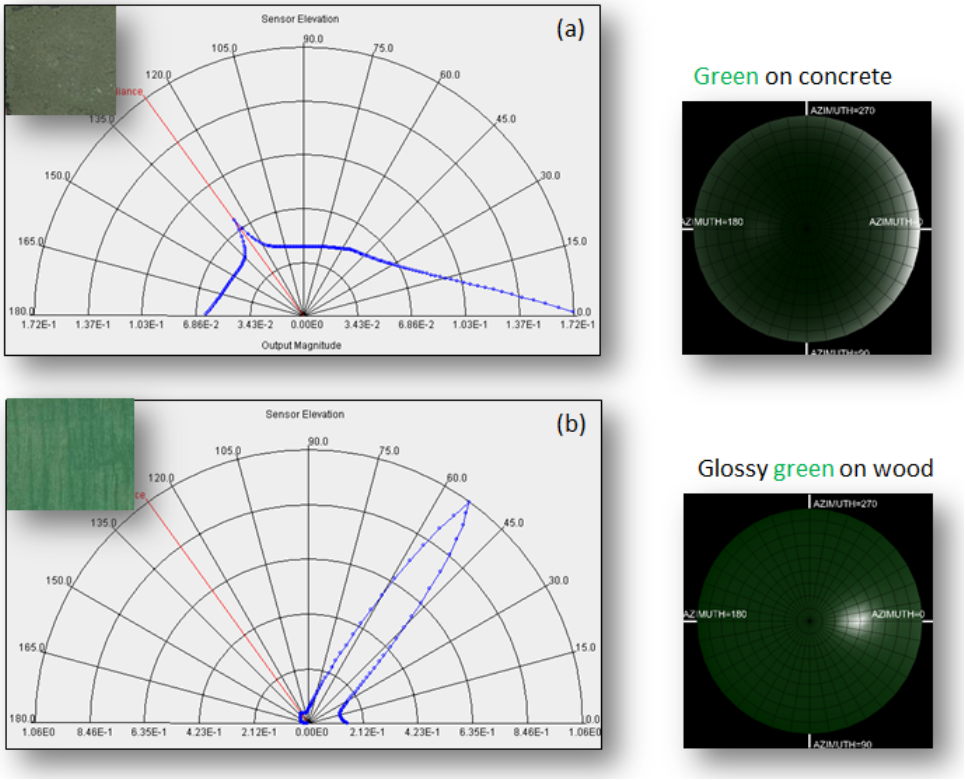


Figure 3.6-10: Simulated BRDF of green paint on (a) concrete and (b) wood materials. Specific illumination angle was 54 degrees at 550 nm. View of 3D BRDF is in the 0 to 180 degree 2D plane.

enhance exploitation of multimodal image data. Previous work focused on developing a detailed enhancement of the MegaScene I DIRSIG simulation scene including additional content and improving the level of detail. Comparisons with real imagery collected by WorldView-2 have also been performed and several statistical metrics show comparable values. The work has been extended to utilize the multimodal imagery collected during the DIRS SHARE 2012 experiment. A detailed simulation of the Avon Driving Park test site including targets deployed is being developed. Simulated hi-res imagery, hyperspectral imagery and lidar imagery will be compared to the real imagery.

Project Status: The project continues through the first part of 2014. Current is focused on preparing the DIRSIG inputs to simulate the Avon Driving Park test site of the SHARE 2012 data collection, and initial analysis of the multimodal data collected over that site.

3.8 ICEsat-Interdisciplinary Advancement of the Theoretical Basis for Lidar sensing of the Earth

Sponsor: National Aeronautics and Space Administration (NASA)
Principal Investigator: Dr. John Kerekes
Research Team:Jiashu Zhang (CIS - Ph.D.), Kim Horan (CIS - MS), 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: Detailed models of the ICESat-2 ATLAS sensor have been developed and used in photon-counting simulations to study returns from horizontal, sloped, and complex surfaces. The modeling work has quantified the mean and standard deviations of elevation bias associated with these various surfaces. The project is ongoing until the summer of 2014.

3.9 Forest Fire Field Experimentation

Sponsor: USDA Forest Service, Northern Research Station
Principal Investigator: Dr. Robert Kremens

RX Cadre - 2012
Project Description:
The RX-CADRE (Prescription-fire (RX) Coupled Atmospheric Dynamic Research Experiment) took place during a three week period in November of 2012 at Eglin Air Force Base near Valparaiso, Florida. This experiment was the largest and most extensively funded fire research experiment in the US to date. The experiments were designed to bring researchers from all fields of fire research together in one comprehensive and extensively instrumented wildland fire experiment. Co-investigators on these experiments included various research branches of the USDA Forest Service (Pacific Northwestern, Rocky Mountain, Southern and Northern), the University of Montana, University of Idaho, San Jose State University, University of Alaska, NASA, the US Air Force, NOAA, and of course RIT.

Project Status:
Over 100 scientists and staff were involved in this three week long experiment. RIT provided 50 sensors for ’point’ in-fire measurements of radiative flux density, convective flow and CO/CO2. This set of sensors was deployed on 9 separate fire experiments during the experiment period. We also deployed the WASP airborne fire sensor on 3 large scale (1000-2000 ha) experiments in this series to provide a synoptic overview in addition to the 20-30 ’point’ measurements taken with the in-fire instrumentation. Other researchers operated instrumented UAVs, full-scale smoke sampling aircraft, meteorological measurement stations, smoke sampling balloons, airborne and ground-based LIDAR and a host of ecological and biological sampling/monitoring instruments. Figure 3.9-11 shows the experimental layout on one of the 6 ’small-series (10 ha) experiments. In Figure 3.9-12 we show an example airborne image from a large scale experiment (1000ha) as captured by the WASP sensor.

Figure 3.9-11: This picture shows the experimental layout of 25 RIT instrument towers deployed on one of the 10 ha ’small-series’ fire behavior experiments on a grassland field at Eglin AFB, Florida. All the instruments here were RIT developed except for the tripod at the left-center of the photograph.

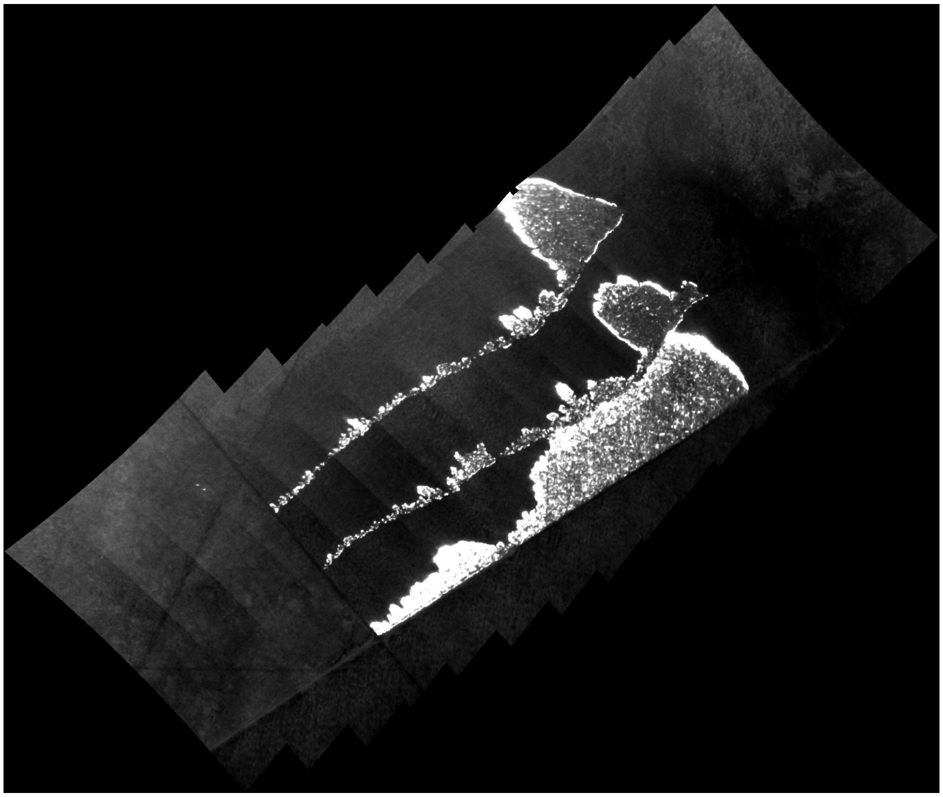


Figure 3.9-12: This is a long-wave infrared image from the WASP sensor package taken midway through the evolution of the fire. The area shown is about 1000 ha and the active fire fronts are clearly distinguishable as is the hot ground in back for the active fire front.

Measurement of Fundamental Wildland Fire Remote Sensing Observables

Project Description:

Wildland fire has been observed by aircraft and satellite for decades but the fundamental physical observables of the fire emissivity, angular distribution of radiation and spectrum have not been measured conclusively. We have undertaken a series of measurements in conjunction with the USDA Forest Service Rocky Mountain Research Center Firelab (Missoula, MT) to measure develop instruments and measure these basic observable parameters. Our first experiment measured the radiation energy emission symmetry of a wildland fire flame. We used a series of nine RIT-developed narrow angle infrared radiometers to observe the fire from three altitudes and three azimuths around a centrally placed fire. In addition to assisting with these experiments and developing the main instruments, RIT constructed the data collection and timing system that included 3 orthogonal synchronized video cameras, total energy radiometers and numerous thermocouple probes to monitor the location and symmetry of the flames. We are currently analyzing the data from this experiment and planning another experiment for the winter of 2014 to measure the effective emissivity of a wildland fire flame. Figure 3.9-13 shows the experimental apparatus as set up in the main combustion chamber of the Missoula Firelab, while Figure 3.9-14 shows a close up of the 0.3o field-of-view infrared radiometer developed for this project.

Figure 3.9-13: A photograph of the experimental set up in the main combustion chamber of the USDA FS Missoula Firelab. The semicircular bows support 9 narrow angle radiometers and other instruments used to monitor the symmetry of radiation form the fire.

Evaluating Forest Fire Fuel Treatments Using and Integrated Approach

Project Description:

In this series of experiments we proposed to measure the effectiveness of various fuel treatments used in the New Jersey Pine Barrens. These methods include prescribed fire, herbicide, mechanical removal and combinations of these three methods. This is a multi-year project that will use both landscape scale (LIDAR and WASP airborne measurements) and in-fire field measurements to quantify the effectiveness of fuel

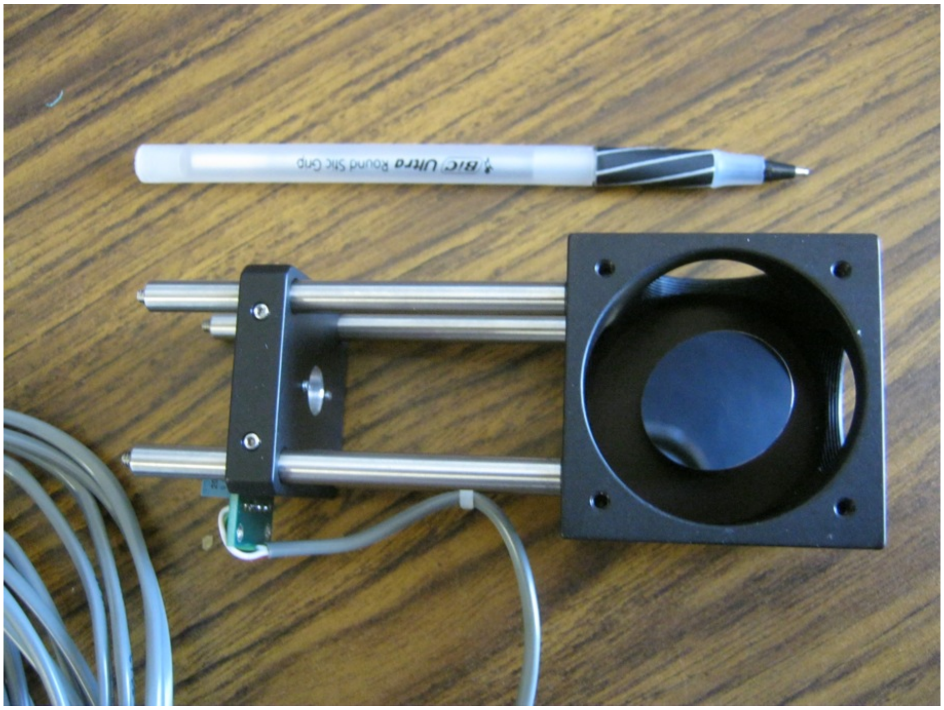


Figure 3.9-14: The narrow angle infrared radiometer developed to measure the radiation symmetry of the fire. The metallic cylinder at the overhead junction of the bows is a mid-wave infrared camera used to monitor the spatio-temporal history of radiation from the fire.

treatments through measurement of structural changes in forest structure and heat release in field plots of from 200 700 acres. This area averages 1500 wildfires burning ca. 7500 acres per year (NJFFS, 1930 to 2010). Large, rapidly progressing, crown fire events occur here ca. every 5-10 years. The most notable major event occurred on the weekend of April 20-21, 1963, when wildfires burned 183,000 acres of forest, destroyed or damaged 186 homes and 197 buildings, and were responsible for 7 deaths. More recently, a wildfire burned 19,225 acres in Ocean County in 1995, and during the late spring of 2007, 15,550 acres burned near Warren Grove and the Garden State Parkway. As a result, fuel reduction treatments are viewed as essential wildfire management practices in this area. The NJFFS and Federal land managers conduct prescribed burns on 16,000 to 24,000 acres per year. These activities are vital because of high population density on the edges of a growth-restricted core area, thus presenting urban-interface issues directly adjacent to nearly continuous fuels. Because of the heterogeneous fuels created here by high frequency of fuels treatments and wildfire, this landscape represents the ideal opportunity to evaluate fundamental questions with regard to landscape-scale fuel treatment effectiveness. In March of this year we flew the WASP airborne sensor over the 400 acre Governors prescribed fire to acquire infrared images and collected data from 12 in-fire measurement stations both for calibration of WASP and as independent point data. The in-fire stations measured infrared flux density, vertical convective flow and temperature profiles along a 6.7 m high instrument tower. The plot was also extensively sampled using conventional field sampling techniques. The data is currently being analyzed with investigators from the USDA Forest Service Northern Research Station and the University of Edinborough. Figure 3.9-15 shows a photograph of one of the 33m meteorological towers that also had RIT radiative flux instruments attached. Figure 3.9-16 shows a photograph of one of the 12 instrument packages deployed on this experiment.

Figure 3.9-15: A 33 m meteorological tower measuring particulates and gas samples in and above the forest canopy. An RIT dual band radiometer was mounted at 8 m on this tower and also at 12 other locations on their own 6.7 m towers.

Fuel Consumption and Carbon Cycling in Northern Peatland Ecosystem

Project Description:

Peatland ecosystems represent 3-5% of the land surface, but sequester 12-30% of soil organic carbon (Gorham 1991). Current trends and climate models predict a general pattern of decreased water availability as a likely outcome of climate change. These climate changes can lead to increased amplitude of water table variation, including large mid-summer declines in water table height. Although peatlands have conventionally been considered resistant to wildfire due to their relatively wet soil conditions, recent studies have shown that the extent of wildfires in boreal North America, where peat fuels are common, has been steadily increasing in recent decades. The increasing extent of burning is likely due to warmer and drier climate conditions, which effectively extends the fire season and increases fire risk and subsequent CO2 emissions. Consumption of fuels and the subsequent emission of carbonaceous species into the atmosphere are dependent on fuel moisture content. Wetter fuels are more likely to exhibit smoldering combustion; this in turn has consequences for the quality of the remaining organics, as well as the composition of particulate emissions to the atmosphere. Understanding peat moisture content will enable an assessment of susceptibility and vulnerability to burning, ultimately allowing a means to model subsequent emissions. State-of-the- art remote sensing techniques are beginning to provide surface moisture maps over large areas.

RIT is teaming with researchers from the University of Minnesota, Michigan Technical University, the University of Michigan and the USDOI Fish and Wildlife Service to study peatlands in the Upper Peninsula of Michigan, in particular in the Seney National Wildlife Refuge in Seney MI. Our role in these experiments will be to measure the radiative power and gaseous emissions from the fire. These parameters will be

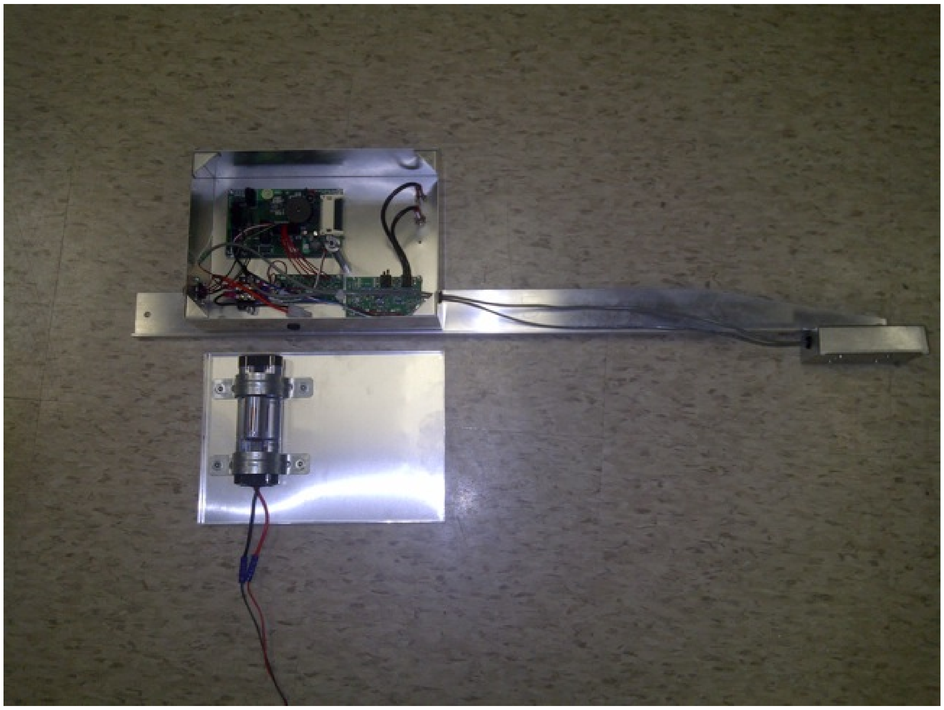


Figure 3.9-16: An instrument package which is deployed on a 6.7 m tower. The arm mounts a dual band IR radiometer (to the right) and a data logger, convective flow gauge and thermocouple interface. (to the left) A rechargeable battery pack powers the unit for up to 2 weeks.

measured using a set of 10 instrument towers each equipped with Co and CO2 sensors and a dual band downward looking infrared radiometer. We deployed the equipment on a prescribed fire in July of 2013 but did not obtain results in the bog as the moisture levels were too high to allow combustion. This experiment will be repeated in 2014 and 2015 at the Seney NWR.

Instrument development for the USDA FS Southern Research Station
We have long been collaborators with the USDA FS Southern Research Station in investigations of fire behavior in the longleaf pine ecosystem of the southeastern United States. Our collaborations have included deployment of RIT instruments and sharing of both airborne and point field data. Our collaborators often do fire experiments with a very short notice, making it impossible for RIT to be involved considering the distances involved. To aid in deployment of instruments on these short notice fire experiments, we have designed and built rugged dual-band infrared radiometers that can be deployed by untrained personal. We have also built a data reduction suite to analyze the data form these instruments based on custom Visual Basic procedures and templates to be used in the Microsoft Excel environment. The primary interest of these researchers is radiant energy release, but we will be able to expand the capabilities of the instrument packages as their needs change. We delivered 10 data collection units during the summer of 2013.

3.10 DHS Data Fusion

Sponsor: Department of Homeland Security / Monroe County Office of Emergency Management
Principal Investigator: Dr. Jennifer Schneider
Co-PI: Donald McKeown

Project Description:
FUSION was a project funded by DHS and administered by the Monroe County office of Emergency Management. The objective was to develop an architecture for integrating various different data sources into a comprehensive information package for a future emergency operations center. The overall project was managed by Dr. Jennifer Schneider in the College of Applied Science and technology (CAST).

The Digital Imaging and Remote Sensing Lab (DIRS) within the Chester F. Carlson Center for Imaging Science was tasked to support the FUSION effort by developing a capability to ingest imagery from a manned aircraft or unmanned air vehicle (UAV) into the County emergency operations information ”dashboard”. Building upon years of development and prior collaboration with the Monroe County Office of Emergency Management, DIRS set out to

1) develop an improved integrated data processing ”workflow” for producing georeferenced imagery in realtime and serving that data via the internet to Monroe County OEM 2) develop a plan for the acquisition of an Unmanned Aerial System (UAS) for collecting airborne imagery by Monroe County

The motivation for addressing the two task areas described above is that we recognize that imagery is not useful unless it is accessible to the user in a timely manner. To achieve this objective, automated or semi-automated processing is needed when collecting large amounts of imagery for applications such as disaster response. Secondly, once the imagery is processed, it must be delivered in a format that is easily accessible to users in an emergency operations organization. Finally, the tremendous advancement in lightweight, low power imaging, computing and navigation electronics has made small UASs a practical and affordable option for acquiring aerial imagery by local emergency management organizations.

We have successfully accomplished these goals as described herein. While hardware procurement was not included in the scope of the effort, we have established the software infrastructure and investigated the procurement options such that procurement could proceed once, or if, it is approved. The DIRS lab at RIT has successfully executed substantial improvements to the existing software architecture for airborne imagery processing enabling nearly fully automated processing in realtime. We have also added a new imagery server system that makes processed imagery data available over an internet link to Monroe County users via a standard ESRI Arc interface.

Finally, we have investigated the technical and regulatory issues for procurement of an affordable aerial imaging UAS for County OEM use. It may come as no surprise that the main stumbling blocks are regulatory and not technical in nature. At this time we recommend that the county defer procurement of a UAS until the Federal Aviation Administration (FAA) has established realistic regulations for small UAS use by public agencies.

Enhancements of Image Processing Workflow for FUSION project
One of the goals of the FUSION project was to implement an improved workflow that is more automated and reduces the latency (delay) in getting airborne imagery to the user. The RIT DIRS lab performed three major tasks to meet this goal:

1. developed enhanced internal data network for transferring large image files
2. developed automated file transfer and data processing management software scripts
3. installed and integrated an ESRI -based high performance WMS-based image server

UAS Study
Given the current restrictive environment imposed by the FAA on public UAS operations, even for the smallest aircraft, it may not be worthwhile at this time to pursue the matter. For example, even if the county obtains a Certificate of Authorization (COA) for UAS operations in an area away from the city, it is of little practical use for other than training as it would not help for urban use or other locations that

are outside that approved area. However, it may be useful to gain some experience in UAS operations in anticipation of the FAA coming up with a more flexible policy for small UAS. RIT is willing to assist Monroe County in this process.

Another approach is to use a large interior space such as a aircraft hangar or indoor sports arena to practice small UAS operations and gain familiarity with UAS systems. No special FAA approval of any sort is required for indoor operations.

Should Monroe County decide to proceed, RIT recommends that the County take a phased acquisition approach for UAS operations beginning with acquisition of at least two or three small, low cost units (about $200 each) that can be operated in a large indoor space such as a sports arena or aircraft hangar. This would provide county personnel with initial experience in UAS operations. Once personnel gain proficiency in basic UAS operations, then the county can decide if it wants to procure a more elaborate system (RIT recommends two units) that can carry a small camera and conduct training in image collection and processing. At this point applying for a COA for testing would be appropriate. In the meantime, hopefully the FAA will provide more realistic guidance for small UAS operations that would enable the implementation of a more useful operational UAS architecture.

3.11 DIRSIG Process Modeling: Feature Extraction to Aid Model Development

Sponsor: Department of Energy, Nuclear Nonproliferation Security Administration

Principal Investigator: Dr. David Messinger
Research Team: Weihua Sun, Jianqing Sun (CIS - Ph.D.)

Project Description:
To aid in large scale model development of industrial sites, particularly with the goal of implementing industrial process models, requires the collection of spatial and temporal information about the site of interest. This is particularly challenging in regions where accurate ground truth is not available. Feature extraction from satellite imagery is a challenging topic. Commercial multispectral satellite data sets, such as WorldView 2 images, are often delivered with a high spatial resolution panchromatic image (PAN) as well as a corresponding low-resolution multispectral spectral image (MSI). Certain fine features are only visible on the PAN but difficult to discern on the MSI. Past work has focused on road network extraction, building footprint extraction, and development of the infrastructure in our DIRSIG modeling environment to incorporate long time scale temporal process phenomenology. Here we describe a novel pan-sharpening technique that has been developed to utilize the high resolution panchromatic information with the multispectral information available from commercial satellite systems to aid in the feature extraction process.

Our approach assumes that each pixel spectrum in the pan-sharpened image is a weighted linear mixture of the spectra of its immediate neighboring superpixels; it treats the spectrum as its smallest element of operation, which is different from most existing algorithms that process each band separately. Our approach is shown to be capable of preserving salient features. In addition, the process is highly parallel with intensive neighbor operations and is implemented on a general purpose GPU card with NVIDIA CUDA architecture that achieves approximately 25 times speedup for our setup. We expect this algorithm to facilitate fine feature extraction from satellite images.

Project Status:
This program is ongoing and will be completed in the summer of 2014. Additional work is being conducted in visualization techniques for geospatial information from real imagery as well as modeled data in GIS systems across multiple modalities. Previously we had developed a simulation of a natural gas fired power plant using a notional process model. Currently we are also developing a high fidelity model of an

aluminum processing plant to simulate a manufacturing process with raw materials entering the plant and final products leaving, with active processes ongoing at the plant observed by external signatures.

3.12 SHARE 2012 Collection Campaign

Sponsor: DIRS IR&D

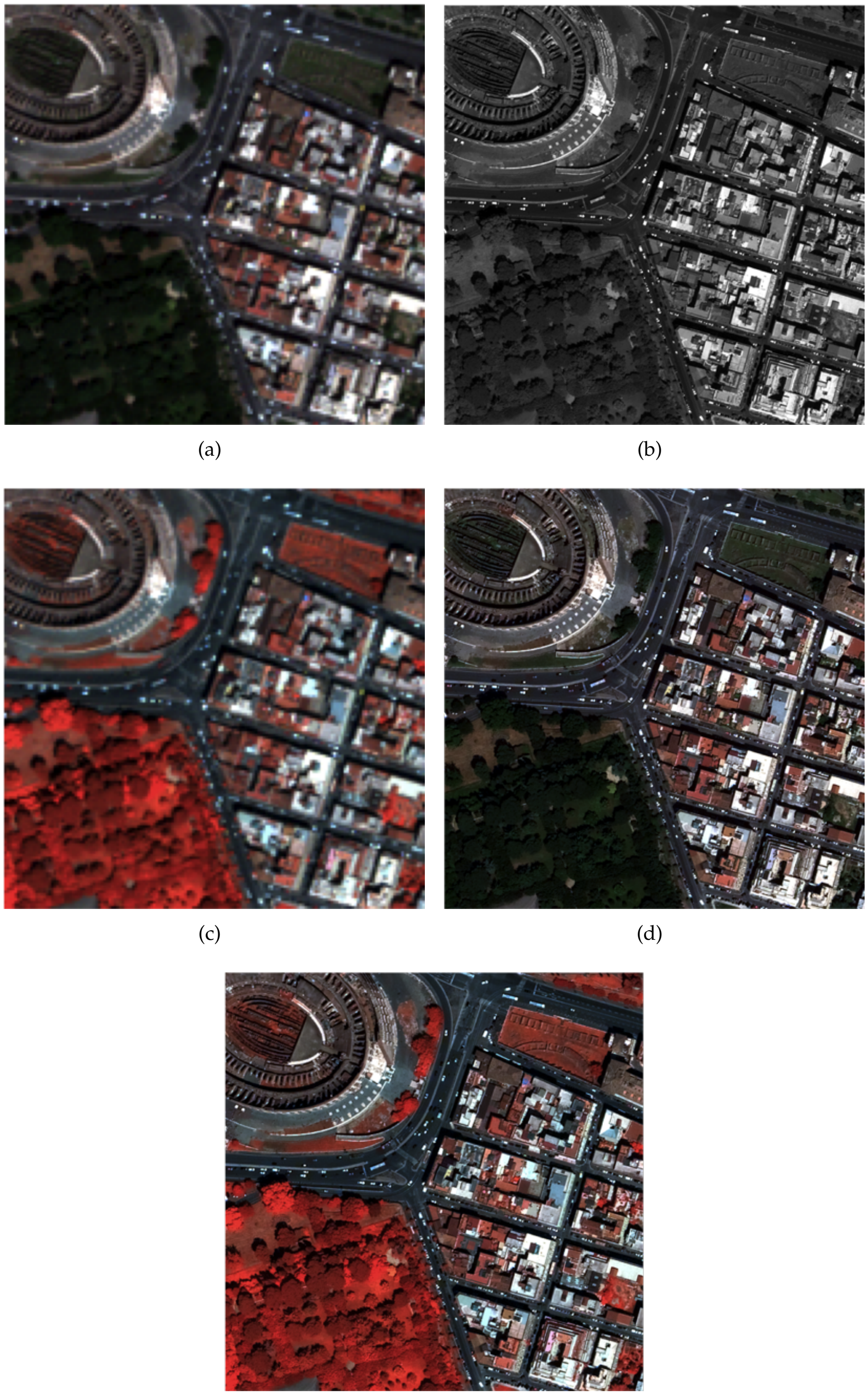
Project Description:
In September of 2012, the DIRS laboratory conducted a large scale, multi-model experimental campaign termed SHARE 2012. The goals of this campaign were many, but primary among them was the collection data set by as many remote sensing platforms as possible, with a large number of well characterized ground truth targets, supporting a wide variety of remote sensing applications. To this end, the SHARE 2012 campaign included several airborne and space-based imaging systems:

- RIT WASP camera system
- airborne LIDAR
- airborne nadir-looking hyperspectral imagery
- airborne oblique hyperspectral imagery
- airborne multispectral, polarimetric, motion video
- space-based multispectral imagery from two platforms (GeoEye and Worldview-2)
- space-based hyperspectral imagery from the HICO sensor on the International Space Station

In addition to these imaging systems, there were several ground based spectrometers, GPS location sensors, atmospheric characterization via locally launched radiosondes, and ground based LIDAR collections.

The collection and planning of the experiment lasted for over nine months, with participation by most members of the DIRS laboratory faculty, staff, and students. Experiment plans were developed for tasks such as sub-pixel target detection, target detection in varying illumination conditions, spatial-spectral target detection, spectral unmixing, LIDAR point cloud change detection, search and rescue, in-water target detection (conducted on Conesus Lake), as well as several others. Figures 3.12-18 & 3.12-19 show two images collected over the main target field in Avon, NY, collected by the RIT WASP sensor and the SpecTIR Prospectir hyperspectral imager.

Another goal of the campaign was to provide the data to the remote sensing research community. Figure 3.12-20 shows the data dissemination web portal developed for this effort. In addition to web-based resources for data download, the web page contains all of the experiment plans and associated ground truth and provides an excellent resource for the community.



(a) (b)

(c) (d)

(e)

Figure 3.11-17: Example of results of pan sharpening algorithm. (a) RGB image of the Colliseum in Rome taken with the Worldview-2 sensor (b) Corresponding panchromatic image (c) Color IR image (d) pan sharpened RGB, and (e) pan-sharpened CIR.

Figure 3.12-18: Image of the main target deployment field during the SHARE 2012 collect as imaged by the RIT WASP sensor.

Figure 3.12-19: Image of the main target deployment field during the SHARE 2012 collect as imaged by the SpecTIR hyperspectral imaging system.

SHARE 2012

SpecTIR Hyperspectral Airborne Experiment 2012

Welcome

About Share:

The SpecTIR Hyperspectral Airborne Experiment (SHARE) 2012 data campaign took place on September 20th, 2012. Run by the Digital Imaging and Remote Sensing (DIRS) Lab in association with industry partners, the data collection was conducted in and around Avon, NY. The ultimate goal of this campaign was to collect and distribute a well ground truthed dataset to the remote sensing community. The documentation for this dataset is available here, and the data may be downloaded from the downloads page.

The Digital Imaging and Remote Sensing (DIRS) Lab is a part of the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology.

News:

Data is Now Available!

- RIT WASP (Vis, SWIR, MWIR, LWIR)
- Kucera Leica ALS-50 LIDAR
- SpecTIR HSI
- MITRE polarmetric HSI video oblique
- 2 Radiosonde launches
- Weather station
- Spectral Ground Truth
- Ground Based LIDAR
- GPS & Photo Documentation

Figure 3.12-20: The web portal hosted at the DIRS web page for dissemination of the data and associated ground truth.

3.13 Graph-Based Approaches to Spectral Image Analysis

Sponsor: NGA University Research Initiative

Principal Investigator(s): Dr. David Messinger
Research Team: Jamie Albano, Amanda Ziemann, Leidy Dorado-Muñoz, Lei Fan (CIS - Ph.D.)

Project Description:
This research project has focused on the development of detection algorithms for spectral imagery based on graphical models of the data in the spectral domain, as opposed to statistical or linear geometrical models. With the advancement of spectral sensor technologies and the improvement in spatial and spectral coverage and resolution, spectral image data (particularly hyperspectral imagery) are typically very non-Gaussian and have significantly nonlinear structures in the spectral domain. We have developed several algorithms for analysis of spectral imagery in areas such as change detection, anomaly detection, and classification that do require such assumptions about the data and have demonstrated promise for robust algorithmic performance in challenging, complex scenes

One algorithmic approach involves the development of the Commute Time Distance (CTD) data transformation for hyperspectral imagery. The CTD transformation is a nonlinear data transformation that has the properties of identifying and enhancing structures in the data based on the graphical representation of the pixels in the spectral domain. The CTD transformation essentially represents the data in a space where the distance between two pixels represents the time it would take a random walker to move along the graph between the two nodes, and then back again (thus the commute). Consequently, pixels that are close to each other in the spectral domain, and are part of a highly connected part of the data cloud have small commute times. The result is that compact dense clusters become even more compact, and the between cluster distances are enhanced as well. Figures 3.13-21 & 3.13-22 demonstrate this for hypespectral imagery of a field with targets placed in it. In Figure 3.13-21, four two-band projections of the spectral data are shown, demonstrating the overlap between the background and target pixels. In Figure 3.13-22, we show two-band projections for the first four bands in the CTD transformed space, highlighting how in the new space the man-made targets are well separated from the background and much simpler to detect.

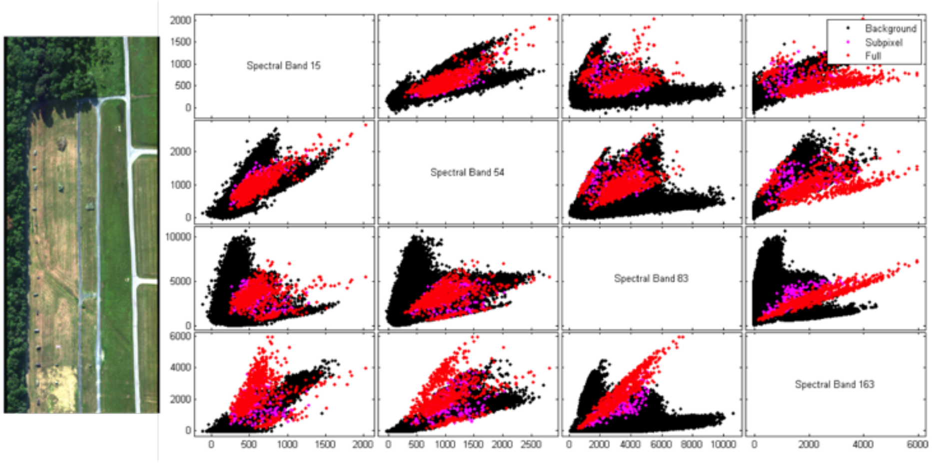


Figure 3.13-21: Two-band projections of hyperspectral data showing the overlap between background pixels (black) and full and sub-pixel targets (red & magenta).

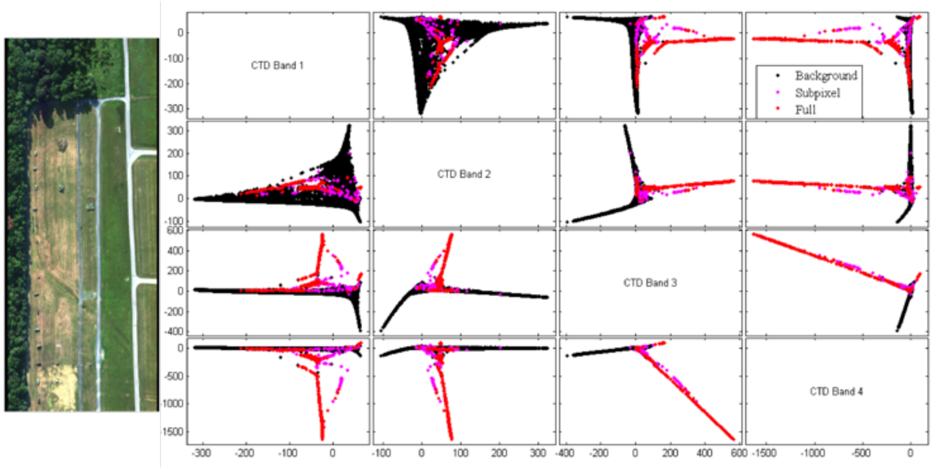


Figure 3.13-22: Projections of the same data after the Commute Time Distance transformation, showing the data projected into the first four bands of the transformed space. Colors are the same as in Figure 3.13-21.

Other research under this project focuses on the development of target detection algorithms for hyperspectral imagery after transforming the data into an estimated set of manifold coordinates. Here, we use the Local Linear Embedding approach to estimate the nonlinear manifold the data lie in spatially local areas. Once the manifold coordinates are established, linear detection algorithms such as the Adaptive Coherence Estimator (ACE) can be applied in the manifold coordinate space. Another project uses the estimated background components from the Topological Anomaly Detection (TAD) algorithm both as training data for supervised classification algorithms as well as for background model characterization in several target detection schemes. The overall goal of this program is to develop novel mathematical approaches to algorithm development to provide new, robust detection algorithms for hyperspectral imagery.

Project Status:
This project has been on-going since 2007 and will finish in the fall of 2013. Further work is ongoing under additional support.

3.14 Analysis of Compressive Sensing for Hyperspectral Remote Sensing Applications

Sponsor: NGA University Research Initiative

Principal Investigator(s): Dr. David Messinger
Research Team: Maria Busuioceanu (CIS - MS)

Project Description:
Compressive Sensing (CS) is a new approach to data collection that has gained the interest of several in the remote sensing community. The primary idea is based on the concept of data compression. If we can collect a full set of data and leverage correlations and structures in the data to compress it after collection, can we simply collect the data sparsely using the same correlations to simply create a smaller dataset which can then be reconstructed into the full data set. Compressive sensing has been proposed for hyperspectral

imaging during which the CS system does not directly measure each voxel in the data cube, but instead measures a multiplexed linear projection of the data which is they subjected to an nonlinear image reconstruction step to produce the full image. CS systems have been shown to produce good imagery at very low sampling rates (¡10%) when the imagery are subject to visual inspection in situations such as medical imaging. Here, the goal was to determine the utility of CS for remote hyperspectral sensing in which maintaining the radiometric fidelity of the imagery is of significant importance for processing algorithms. Figure 3.14-23 shows the basic CS concept as implement in the Coded Aperture Snapshot Spectral Imager - Dual Disperser (CASSI DD) system studied here. After collection of the CS measurements, a nonlinear spectral - spatial image reconstruction algorithm is applied to the data to construct the final image cube. The image cubes were then studied here as to their applicability for typical hyperspectral tasks such as classification, anomaly detection, and target detection.

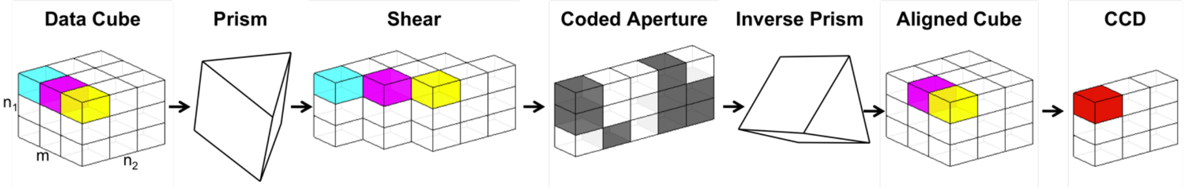


Figure 3.14-23: Schematic of the operation of the CASSI DD compressing sensing hyperspectral imager.

One aspect of the study was an investigation into how atmospheric compensations algorithms will be able to accurately estimate surface reflectance in compressively sensed imagery. The standard compensation algorithm FLAASH was applied to simulated CS HSI collected at varying levels of sparse sampling and several surface reflectance spectra were then analyzed. Figure 3.14-24 shows the derived spectra of a target panel in a hyperspectral scene after CS measurement, image reconstruction, and then atmospheric compensation. Note that as we sample less of the data (as r decreases) the fidelity of the estimated target spectrum is dramatically altered. This was further shown to dramatically decrease the performance of target de-

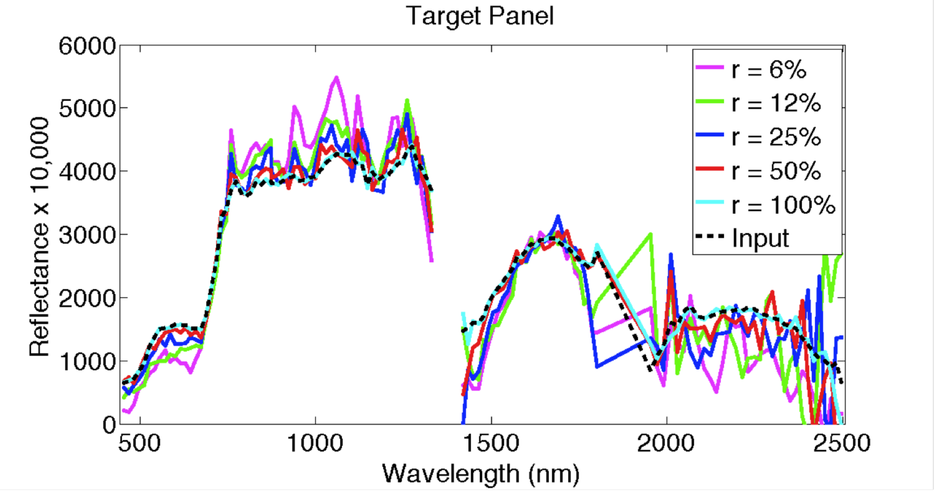


Figure 3.14-24: Reflectance spectra derived CS HSI after atmospheric compensation. The parameter r is approximately the percentage of measurements taken relative to the full traditional hyperspectral imagery shown as the black dashed line.

tection algorithms. However, we observed that spectra were not so poorly reconstructed as to limit the effectiveness of classification algorithms.

Project Status:
This project was completed in the summer of 2013. Results from this studied indicated that while Compressive Sensing is useful for visualization of RGB imagery, the CS measurement and image reconstruction process and dramatically altered both individual spectra as well as the overall data cloud in the spectral domain. Consequently hyperspectral applications that require accurate spectral representations of materials on the ground are not well served by compressive sensing of hyperspectral remotely sensed data.

3.15 Voxel-based LIDAR exploitation

Sponsor: DIRS IR&D

Principal Investigator(s): Dr. David Messinger
Research Team: Shea Hagstrom (CIS - Ph.D.)

Project Description:
This project continues to develop voxel-based approaches to analysis of LIDAR point cloud data to improve our ability to exploit the data for various applications. Previous work considered the problem of line-of-sight analysis in complex urban environments and demonstrated how representing the point cloud data in a voxel map increased the confidence levels in the derived line-of-sight map. This year, the project moved on to using a voxel-based LIDAR analysis approach, fused with high resolution visible imagery, to produce geometrically accurate, geo-referenced imagery. Figure 3.15-25 shows the basic process which requires both a LIDAR point cloud and RGB imagery collected from multiple look angles. The use of the 3D voxel model allows ortho images to be generated from any desired viewpoint and perspective.

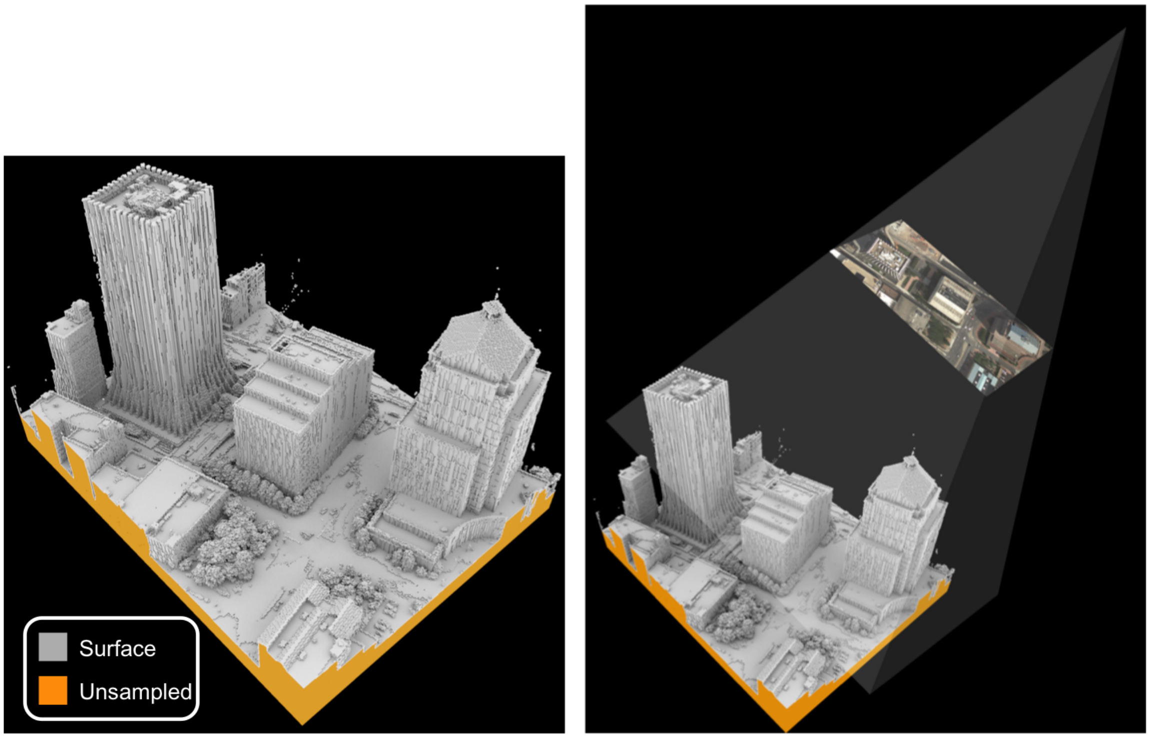
Figure 3.15-26 shows the results of this process for data collected over downtown Rochester, NY. Here, we compare our voxel-based ortho image with a traditional ortho image. Note that our method alleviates problems related to overlapping geometry and perspective issues associated with tall structures.

Project Status:
This project is ongoing, developing new algorithms for extraction of quantitative information from LIDAR point clouds using a voxel-based model. Additional work is being conducted into object detection under highly obscuring forest canopies and three dimensional change detection. All of these approaches leverage both the LIDAR point cloud as well as the aircraft position and pointing information to represent the data in a three dimensional voxel map. However, one drawback of this approach is the size of the voxel map that is created. Consequently, care should be taken to appropriately choose the resolution of the voxel map relative to the size of the object of interest in the scene.

3.16 SHARE Boot Camp Project

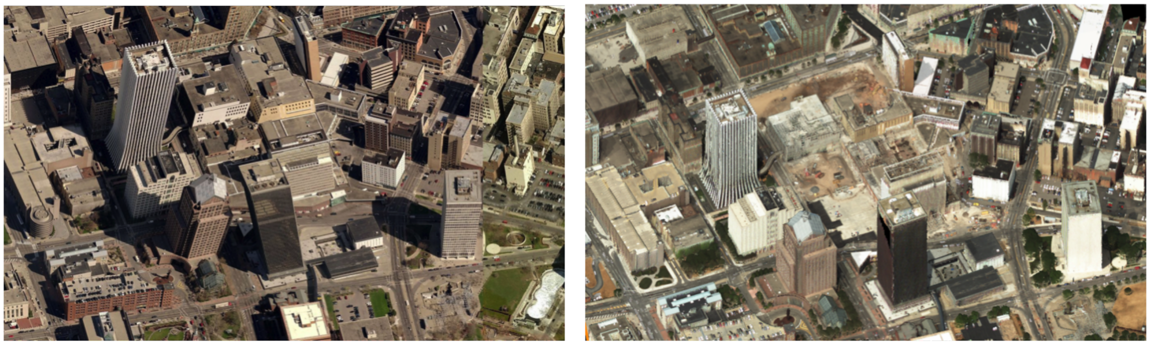
Sponsor: Office of the Vice President of Research
Principal Investigator: Erin Ontiveros

Project Description:
The Digital Imaging and Remote Sensing (DIRS) Laboratory executed a large scale remote sensing field collection effort in a local Avon, NY park. The collection was called SHARE 2012, as the imagery and data collected is shared freely on the internet. This collection included several experiments that were planned on



(a) (b)

Figure 3.15-25: Creation of a "true" ortho image using a voxel LIDAR point cloud model. (a) The voxel model derived from the point cloud. (b) Projection of the high resolution RGB image from the camera position onto the voxel model.



(a) (b)

Figure 3.15-26: Comparison between traditional ortho photo and voxel-derived ortho photo. (a) Traditional ortho photo. (b) Ortho photo derived from projection onto the voxel model.

the ground and imaged using several airborne imaging sensors and satellites. These sensors cover different regions of the electromagnetic spectrum and their pixels represent different distances on the ground. This project involves the search and rescue experiment that was organized and enacted during this effort. It involved placing human subjects in predetermined positions in a field and under significant tree coverage in an attempt to find them using data from the various sensors.

Figure 3.16-27: An example of how people were positioned sitting, standing and laying in the outfield of a baseball diamond (taken by a hand held camera) during the collection.

Figure 3.16-28: Example of person positioned on the trail under tree coverage

Figure 3.16-29: Example of tree coverage above person on the trail

The subjects were given specific shirts to wear, to try to constrain the variability of such a complex problem, i.e., each subject is a different height, weight, ethnicity, hair color, and wearing a different outfit. The shirt materials used were as follows: yellow polyester, white polyester, white cotton, and a white cotton/polyester blend. These colors and blends were selected based on the work of previous work, in which he determined that yellow polyester was the most detectable combination against grass, and white was of average detectability. The other blends were used because they are common materials and it is important to try to understand their detectability through remote sensing techniques.

The research problem to be explored is to understand under what conditions - electromagnetic regions, pixel ground dimension, clothing materials, physical positions, obscurations, etc. - can someone be detected and even identified using these various remote sensing platforms from SHARE 2012 collection. The specific platforms available from the collection are: the WASP system, SpecTIR Vis-NIR/SWIR HSI, and Digital Globe World View 2.

Figure 3.16-30: Same scenario as described above and shown in Figure 3.16-27 as seen by the WASP system.

The project's goal is to better understand the science of how people are seen and detected in these different types of imagery.

Project Status:
Preliminary work has been done to isolate the imagery and ground truth of interest for this experiment from the several hundreds of images and even more spectra that were collected in the SHARE campaign. The ground truth was then organized into a spectral library for ease of testing various detection algorithms against.

The first step in this study is to see how well the shirt spectra, as seen in Figure 3.16-31, can be detected in the open field, the scenario shown in Figures 3.16-27 and 3.16-30. This is the best possible detection scenario.

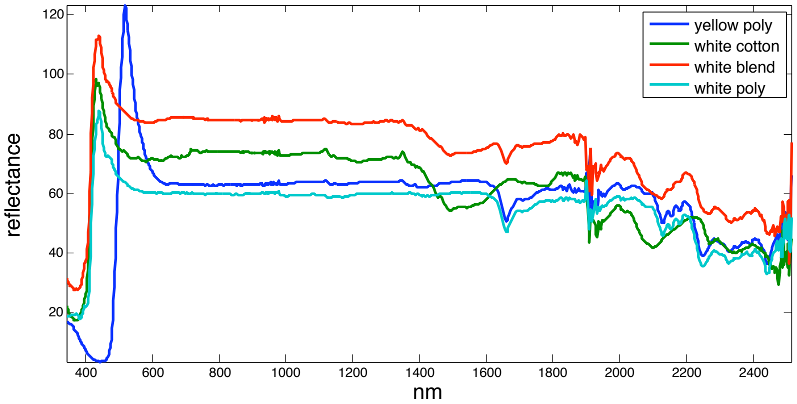


Figure 3.16-31: The ground truth spectra of the shirts worn by the subjects in this experiment. The shirt materials were white cotton, white polyester, white cotton and polyester blend, and yellow polyester.

Using the ENVI detection wizard several algorithms can be evaluated relatively quickly. The algorithms that are successful in this study may show utility in the more difficult, tree cover scenario. However, algorithms that do not prove useful for this scenario will be discarded will not be used for more complex applications. Figure 3.16-32 shows the correct detection of the yellow polyester shirt using the constrained energy minimization (CEM) algorithm.

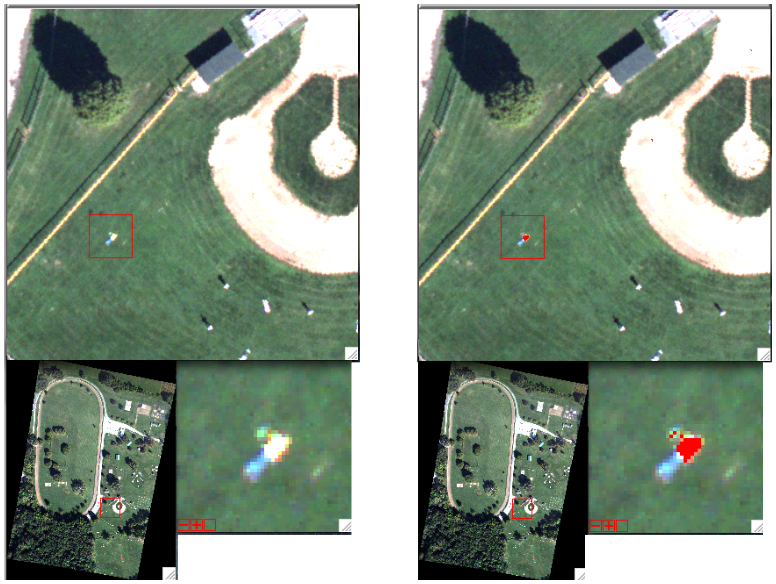


Figure 3.16-32: Preliminary results from the CEM algorithm showing detection of the yellow shirt in the open field from the WASP system. The image collection on the left is prior to processing and the right is after showing the detection in red.

This shows there is potential in using the WASP system to find people wearing a specific shirt. Future work will look at not only other shirts and sensors but also how the sensors being used together may aid in detection.

3.17 LDCM End-to-end System Simulation

Sponsor: NASA - Goddard Space Flight Center
Principal Investigator: Dr. John Schott
Research Team:Dr. Aaron Gerace, Dr. Michael Gartley, Dr. Scott Brown

Project Description:
Landsat 8 was successfully launched from Vandenburg Airforce Base on February11th, 2013. Prelaunch efforts for this project focused on providing support to the Landsat Data Continuity Mission (LDCM) team with an emphasis on modeling and investigating potential radiometric and image quality issues associated with the Thermal Infrared Sensor (TIRS) and Operational Land Imager (OLI). The early years of this work focused on developing the DIRSIG capabilities necessary to model the geometric properties of OLI and TIRS and using the model to identify image quality issues associated with the sensors. 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:
Due to the complex focal plane of the OLI and TIRS instrument, on-orbit side slither (90 degree yaw) ma-

neuvers have been performed to flatfield the instruments. The modeling efforts for the current year used the DIRSIG model to identify worldwide sites suitable for the planned maneuvers and to develop methodology necessary to adequately flatfield the data. Figure 3.17-33 shows the impact of side slither calibration. The left shows modeled data prior to adding non-uniformity effects, the middle shows modeled raw data that one would expect prior to calibration, and the right shows that data after a side slither correction has been applied.

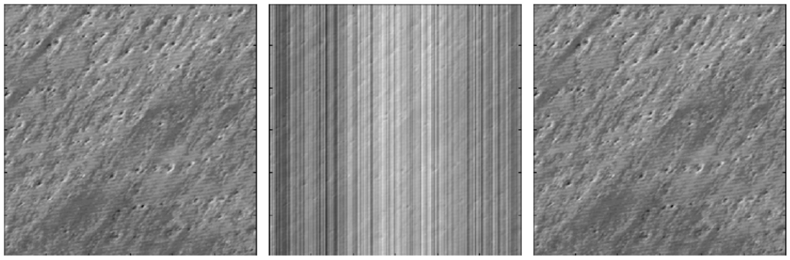


Figure 3.17-33: Modeled data showing the impact of using side slither data to perform flatfield calibration. The left shows modeled data prior to adding non-uniformity effects, the middle shows modeled raw data, and the right shows the data after side slither calibration.

Results from the modeling effort performed in this year's effort were used to plan side slither maneuvers during the commissioning phase of the satellite. Specifically, successful maneuvers were performed over Greenland and Niger and the data used to develop the current version of calibration processing. While the prelaunch efforts of this project used modeling and simulation to support the LDCM team, future efforts will focus on algorithm development and data analysis to support the calibration team to understand on-orbit phenomenology.

3.18 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 recently launched Landsat-8. 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. The final step is to validate our work and develop an error metric to inform users of the fidelity of the final product on a pixel-by-pixel basis.

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.

Batches of scenes were processed over bodies of water from which the surface water temperature can be retrieved, from buoys or lake platforms using JPL's temperature retrieval process or RIT's skin temperature correction method, because the emissivity of water is known. This initial validation dataset included scenes over Lake Tahoe, the Salton Sea, Lake Ontario, the Atlantic Ocean off the Delaware-Maryland coast, and the Atlantic Ocean off the Georgia coast. A histogram of error results, calculated as the difference between the retrieved and ground truth temperature, is shown in Figure 3.18. A negative error indicates an underestimation of the temperature. These results are encouraging for the overall accuracy of our process. We see a large number of results with errors between -1 K and 1 K. From visual investigation, we can conclude that all of the scenes in the left most bin are clouds, and we can segment these with a cloud detection algorithm. A number of other scenes with large negative errors can also be segmented with a cloud detection algorithm. With these results, we need to develop an error analysis methodology that allows us to predict the error associated with each scene, particularly for the set of scenes with moderately large negative errors, between -3 K and -8 K. We also see a slight negative bias in even our best results and need to determine the cause of this. The goal of our error analysis is understand the causes of and therefore be able to predict these errors.

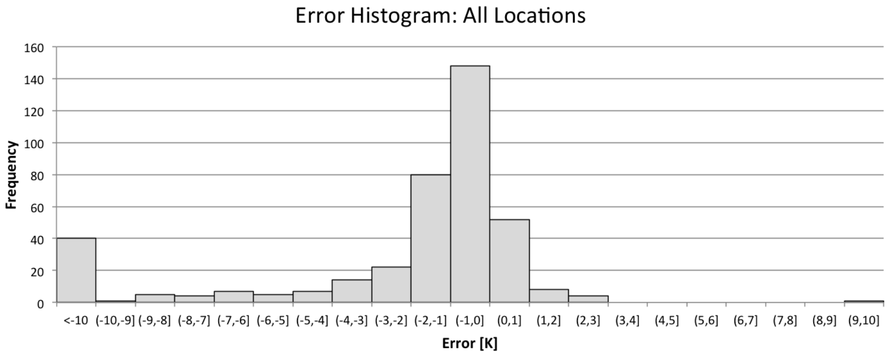


Figure 3.18-34: Histogram of error results, calculated as the difference between the ground truth and retrieved temperature.

Current work is focused on developing a pixel-by-pixel error metric for the final product. Thus far, we have considered three separate methods. We have developed a tool to estimate errors based on standard error propagation from the errors in our input atmospheric profiles. Figure 3.18 shows a plot comparing our predicted and actual errors using this method. As shown, while we can accurately predict some small errors, our error predictions are not accurate enough for most points. We believe that these inaccuracies are due to incomplete characterizations of the atmospheric makeup. The second method predicts errors based on regression of errors against atmospheric variables and the third is a qualitative method based on thresholds for atmospheric characteristics. While the threshold method seems more promising, neither individually provides accurate enough prediction to include in a final product.

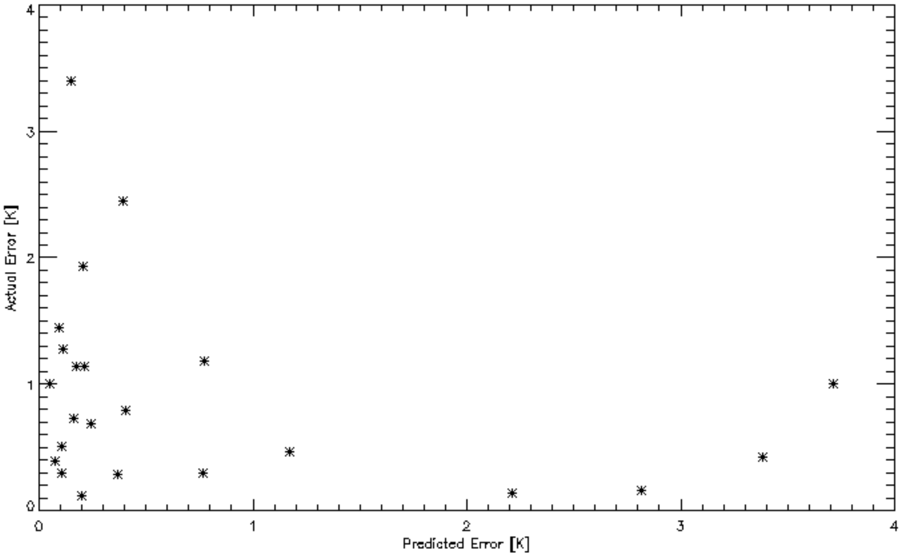


Figure 3.18-35: Comparison of predicted error to actual error for a subset of data points.

The next step is to optimize and finalize an error metric, possibly by combining two of the methods we have already developed. Most importantly, we need to determine how to estimate error by capturing the uncertainty in the atmosphere, particularly the temperature and water content. Other future tasks include extending our validation dataset and implementing minor improvements to the process. A global reanalysis dataset, MERRA, has been identified, and this same process will be implemented for a global product.

3.19 Landsat 5, 7 and 8 Automated Thermal Calibration

Sponsor: NASA & US Geological Survey
Principal Investigator(s): Dr. John Schott
Research Team: Nina Raqueno

Project Description:
This year brought many changes to the Landsat data community with the decommissioning of Landsat 5 and the launch of Landsat 8. On February 11th, 2013, RIT faculty, staff, and alumni gathered at Vandenberg Air Force Base to witness history as the next generation of Landsat was launched.

With the excitement of this launch, came many research opportunities as RIT began to take the first glimpse into the two new thermal bands on Landsat 8. While most of the world was looking at the first officially released scene of Wyoming and Colorado taken on March18, 2013, the RIT team was busy interrogating thermal calibration scenes over large homogeneous water bodies. RIT illustrated many examples of where improvements between SCA (Sensor Chip Assembly) overlap regions were necessary and that further flat fielding was recommended.

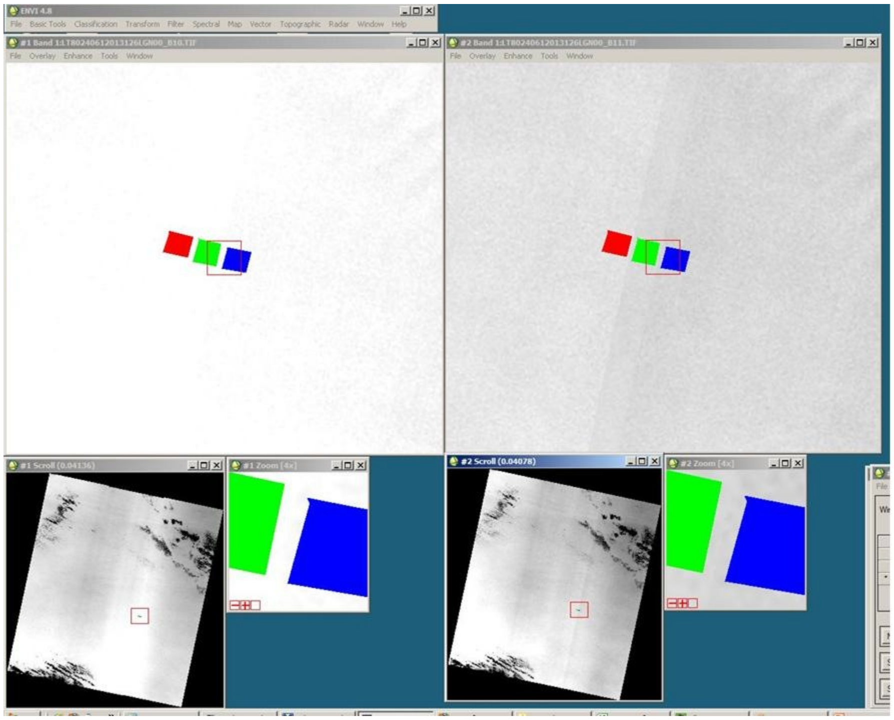


Figure 3.19-36: Thermal Imagery from Open Ocean Collect from May 6, 2013.

As Landsat 8 traveled to its final orbit a unique data collection opportunity arose when LDCM under-flew the Landsat 7 satellite from Mar. 29 to Mar. 31, collecting more than 1,200 coincident scenes. These L7/L8 scene pairs allowed RIT to cross calibrate the L8 using the well characterized L7 thermal band. Our initial findings indicated that the Landsat 8 predicted values were warmer that expected and a correction would be necessary.

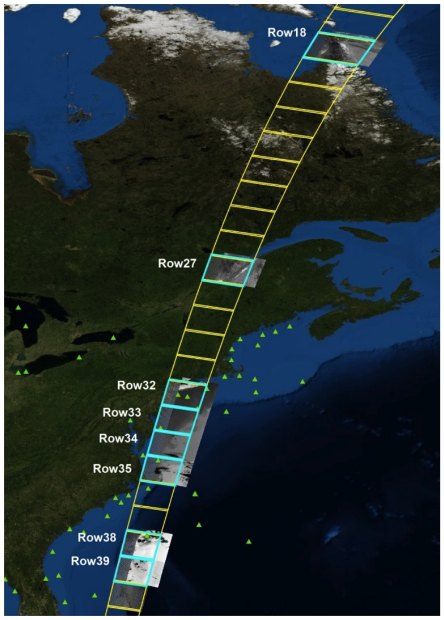


Figure 3.19-37: Example of L7 / L8 Overpass from March 30, 2013. The green triangles indicate buoy locations of known water temperature.

Landsat 8 officially began normal operations on May 30, 2013, when the leadership for satellite operations transferred from NASA to the U.S. Geological Survey and data was released to the public. Since then RIT has continued to process buoy data in order to make recommendations to improve the on orbit absolute calibration for the two thermal bands. The use of the automatic buoy process has greatly increased the amount of thermal ground truth available in a short amount of time. Prior to automation the RIT team would collect only a few data points per collections season and with buoy automation we are adding new calibration data points bi-weekly and have processed 100s of scenes and generated over 40 high quality calibration points in just a few months.

Project Status:

RIT continues to monitor the thermal accuracy of both of the active Landsat instruments (7 & 8). Since launch of Landsat 8, the RIT has participated in bi-weekly telecons with NASA/ USGS Calibration/Validation team by presenting calibration results and making recommendations for adjusting Landsat 8 thermal band 10. RIT meets twice annually with NASA/USGS Landsat Calibration Team to present the summarized results generated from the buoy methodology.

RIT is in the process of making the automatic buoy process more robust by adding new buoys and adding features, such as, error checking for missing input data.

3.20 USGS Landsat Science Team

Sponsor: U.S. Geological Survey
Principal Investigator: Dr. John Schott
Research Team: Dr. Aaron Gerace, Nina Raqueño, Javier Concha Sepulveda (CIS - Ph.D.)

Project Description:

As part of previous Landsat science team studies, the potential to use OLI data for simultaneous retrieval and mapping of the three primary coloring agents in water (chlorophyll, suspended materials and colored dissolved organic material) was demonstrated via simulation, [see Gerace et al. (2013)]. These studies were based on simulations and assumed idealized atmospheric compensation. This effort is targeted at development and testing of methods to demonstrate the actual capability of Landsat 8 for mapping of water quality constituents in fresh and coastal (i.e. Case II) waters. To this end the focus of this first year's efforts were; to conduct field campaigns under Landsat 8 to use in algorithm validation, to improve constituent retrieval algorithms, to develop an initial simplified atmospheric compensation algorithm and to verify OLI on orbit radiometric performance over water.

Project Status:

The radiometric performance of OLI over water was measured by calculating the signal to noise (SNR) (mean/standard deviation) for uniform water targets. These values were compared to the OLI SNR requirements as well as to Landsat 7 observed SNR (see Figure 3.20-38). The OLI instrument was expected to exceed the required values based on pre-lunch measurements. The actual performance significantly exceeded requirements and was more than 5 times better than Landsat 7 for water targets as seen in Figure 1. This is of critical importance since the previous studies had demonstrated that improved SNR was one of the most critical parameters enabling the improved water constituent retrieval predicted for Landsat 8.

Signal-to-Noise Ratio for uniform water regions extracted for a region of uniform brightness in the Red Sea from Landsat 8(circle) along with the specified Signal-to-Noise Ratio for Landsat 8 (diamond) and Landsat 7 (triangle) at typical radiance levels

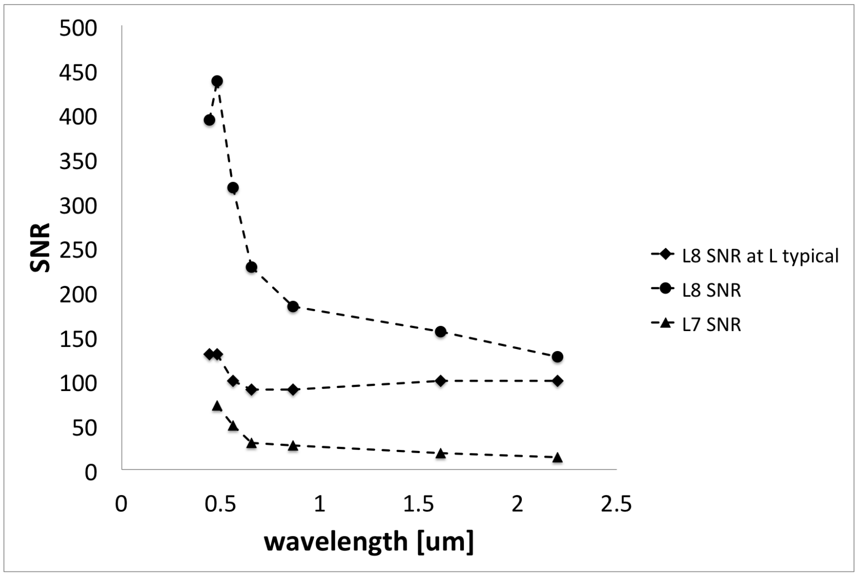


Figure 3.20-38: An improved look-up table (LUT) was built to support/improve the constituent retrieval algorithm. This LUT used a wider range of constituent concentrations based on the higher concentrations observed in field samples.

An initial atmospheric retrieval algorithm was developed and preliminary testing was conducted on Landsat 5 data. Note the L5 data were pixel averaged to reduce spatial resolution in order to improve SNRs to acceptable levels. The algorithm is a model based empirical line method (ELM) approach. It uses a modeled dark target reflectance based on prediction (modeling) the reflectance of a water target assuming the concentration of constituents is known at one location (i.e. in one lake or at one location in a large or complex water body). The reflectance is modeled using an in-water radiative transfer model (Hydro-light) [see Mobley (1994)] that incorporates constituent concentrations, the inherent optical properties of the water, surface roughness and viewing geometry in the modeling process. The bright target uses the average of many urban pixels that had been converted to reflectance using the experimental Landsat reflectance product. This two point per band solution yields a linear solution to the relationship between radiance and reflectance from which the spectrally sampled reflectance of each pixel can be determined. These data are then matched to the best fit to the modeled data in a LUT to determine the constituents. Figure 3.20-39 shows maps of constituents retrieved from Landsat 7 using this process. There was no ground truth taken as part of this process so a detailed evaluation of the approach has not yet occurred. However, a visual analysis shows elevated concentrations of chlorophyll in Long Pond which is known to be highly eutropic. It also shows the Genesee river plume to be dominated by suspended material. Again this is consistent with the fact that the river is loaded with sediment run off from upstream agricultural areas.

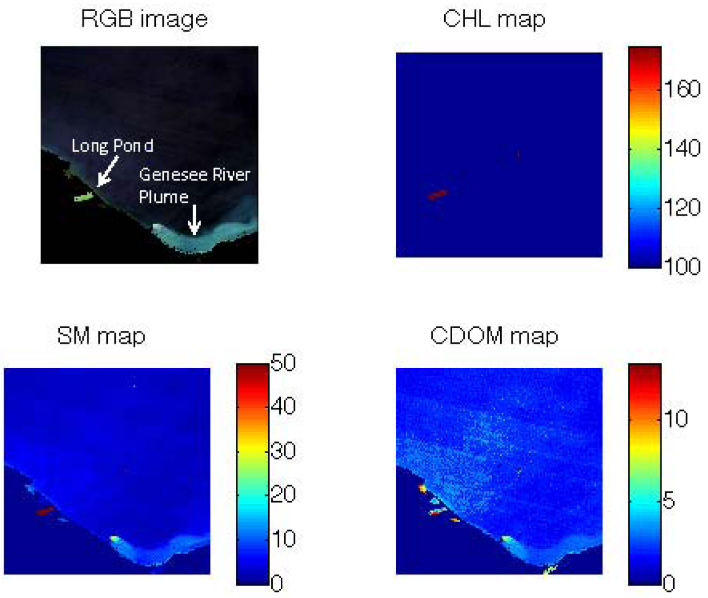


Figure 3.20-39: Portion of a true color Landsat 5 image of Lake Ontario (top left) and derived concentration/absorption maps of chlorophyll (CHL), suspended material (SM) and colored dissolved organic material (CDOM).

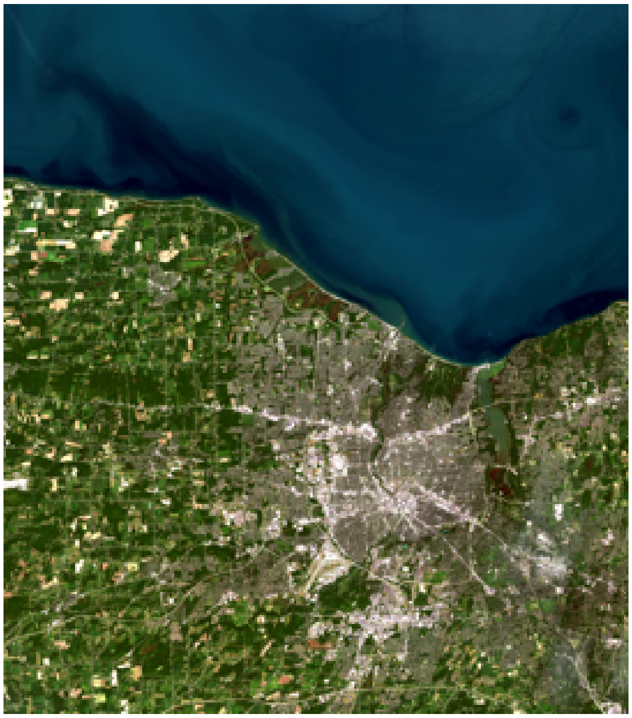


Figure 3.20-40: Landsat 8 image acquired on 8/25/13 showing a whiting event on Lake Ontario.

Limited cloud free access to our primary study site has delayed simultaneous ground truth and satellite data acquisitions. As a result we have; focused on algorithm development, pushed our acquisition season later in the year and identified collaborators in others areas that had better luck with the clouds. Figure 3.20-40 shows a whiting event in Lake Erie on a date where we made a successful field collect in the bays. We had successful collects in September which will allow a productive analytical effort during year two.

3.21 IPLER - The Information Products Laboratory for Emergency Response

Sponsor: National Science Foundation (NSF)
Principal Investigator: Dr. Jan van Aardt
Research Team: Don McKeown, Dr. Tony Vodacek, Jason Faulring, Shagan Sah (CIS - MS), and Dr. Chris Renschler (University at Buffalo)

Project Description:

This NSF Partnerships for Innovation (PFI) project between the Rochester Institute of Technology (RIT) and the University at Buffalo (UB) is focused on innovation in disaster management. The overarching goal of the Information Products Laboratory for Emergency Response (IPLER) is to develop disaster management tools based on remote sensing research and geospatial analysis technology. The integrated team applied a systems engineering approach to define user needs in disaster management, perform targeted research and develop commercial disaster management products, and establish a sustainable infrastructure for technology transfer to aid commercial collaborators. IPLER facilitated economic development and commercialization by establishing and maintaining a dialogue between the developers and providers of technologies and the people who use them in disaster response. Finally, students at RIT and UB were also actively engaged in the targeted research and will be uniquely qualified to contribute to the disaster management chain. A synopsis of the project funding and affiliated projects are shown in Figure 3.21-41. This figure shows how the IPLER initiative was a direct consequence of preceding hardware development and research efforts, and also has led to numerous follow-up grants.

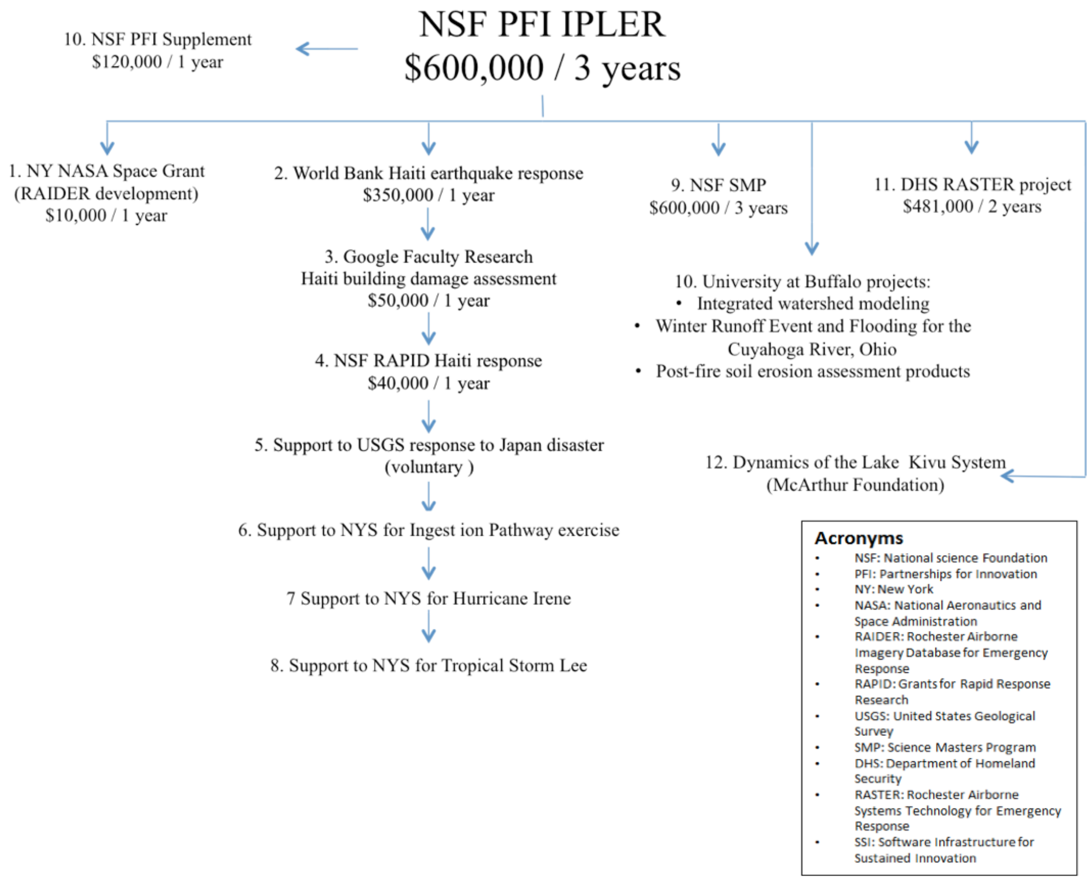


Figure 3.21-41: An overview of the sustainable growth of the NSF-funded Partnerships for Innovation (PFI) project: The Information Products Laboratory for Emergency Response.

An overview of the sustainable growth of the NSF-funded Partnerships for Innovation (PFI) project: The Information Products Laboratory for Emergency Response

Project Status:

A variety of successful activities were completed under the banner of this final-year project. These include:

IPLER short course (2012-2013): The RIT IPLER team developed and presented a 1-day short course on the application of remote sensing for disaster response. The course was presented to approximately 35 IPLER workshop participants and included the topics of:

- Imaging Systems

  - key remote sensing physics and technical concepts
  - remote sensing data sources and visualization tools
- Image visualization
  - photo interpretation
  - examples of elements such as shape, texture, shadow, resolution, etc
- Image classification
  - unsupervised classification
  - supervised classification
- Integration of imagery with GIS
  - Overview of ESRI ArcGIS
  - practical exercises in integrating example imagery with map data

Flight Demonstration (2012-2013): During the spring 2012 IPLER workshop, RIT conducted a live demonstration of an airborne imaging system with a near real-time downlink of map-referenced imagery. Workshop participants were able to watch the aircraft deployment via a live track map and see imagery downlinked from the aircraft displayed on a large screen in a conference center on the RIT campus.

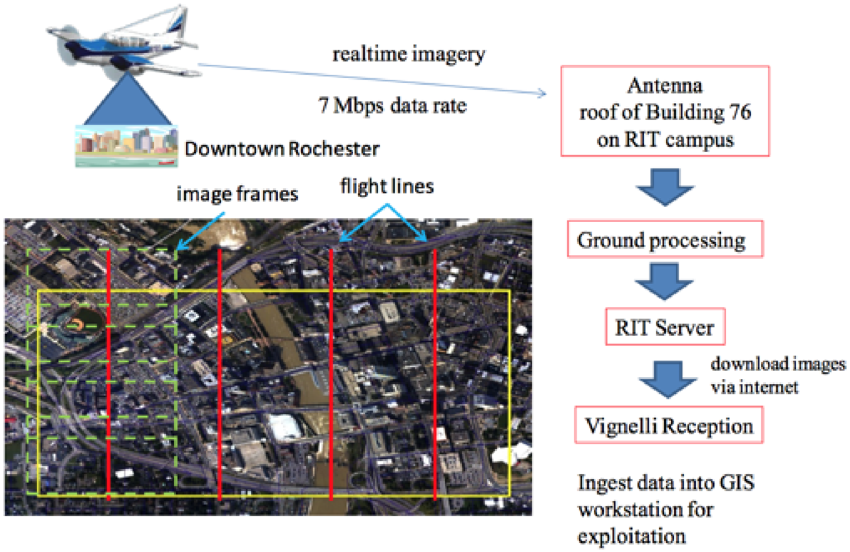


Figure 3.21-42: Live demonstration of IPLER real-time aerial imagery.

IPLER Promotional Video (2012-2013): The RIT VP for Research sponsored the production of a high quality promotional video for IPLER, which can be viewed at `http://www.youtube.com/watch?v=m7LkfQB6Rhw`

The two-minute video provides an informative and exciting look at IPLER. Figure 3.21-43 shows a ”screen shot” from the video showing an RIT student viewing satellite image data processed by IPLER of tsunami damage in Japan.

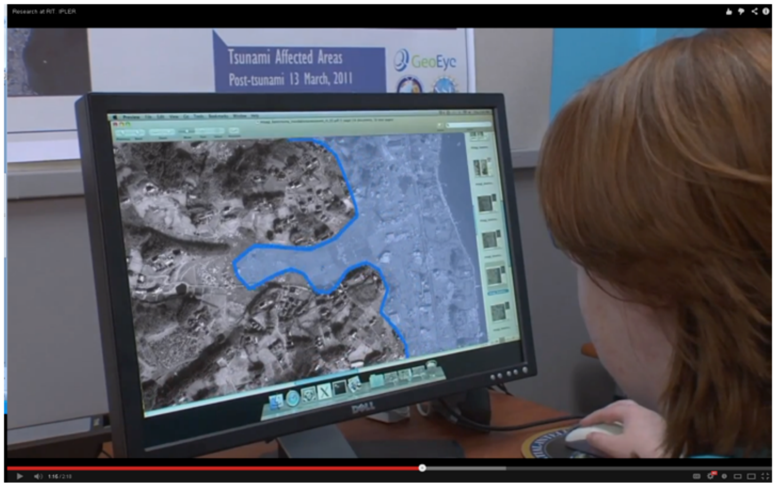


Figure 3.21-43: RIT sponsored promotional video highlights IPLER activities.

Joint Demonstration with Syracuse University WiGiT PFI (2012-2013): The IPLER team has been in preparation for a joint demonstration of IPLER technology integrated with wireless grid radio network technology from the SU Wireless Grids Innovation Testbed (WiGiT). The planned demonstration with local upstate New York emergency services personnel is awaiting completion of the WiGiT technology readiness anticipated for spring 2014. Specific IPLER preparation has included refinement of system software to streamline the real-time data processing workflow.

Superstorm Sandy Response Evaluation Panel (2012-2013): Two members of the NSF IPLER team, Dr. Jennifer Schneider from RIT and Dr. Chris Renschler, IPLER Co-PI, from UB, were invited to sit on a 26 member blue ribbon panel convened by Governor Andrew Cuomo following the devastation wrought on New York State by Hurricane Sandy in late October 2012. The NYS Respond Commission was tasked with finding ways to ensure that New York State is ready to respond to future weather-related disasters. The Commission examined and made recommendations to improve the planning, training and resource commitment that must occur before the next major weather event in order for the appropriate deployment of people and resources to take place during and after the emergency or disaster occurs.

The Commission was co-chaired by Thad Allen, Senior Vice President at Booz Allen Hamilton, and Admiral (US Coast Guard, Retired), and Brad Penuel, Director of the Center for Catastrophe Preparedness and Response at New York University. The Commission's recommendations were provided to the Governor on January 3, 2013 and addressed the following issues:

- sufficient trained personnel can be activated for emergency response and recovery efforts
- the health and safety of hospital patients and other vulnerable persons are protected during an emergency
- the public is provided with reliable and timely information
- every locality has planned and is prepared for a disaster
- emergency responses are effectively coordinated across all levels of government
- adverse events are rapidly responded to and post-emergency needs such as shelter, food, water, electricity and essential appliances are identified and met

Among the specific panel recommendations to the Governor were some key focus points of the IPLER enterprise: ”Use social medial, real-time mapping and other tools to provide up-to-the-minute information on emergency resources.” (PowerPoint presentation of NYS Respond Commission)

3.22 NEON Post Doc

Sponsor: National Ecological Observatory Network (NEON)
Principal Investigator: Dr. Jan van Aardt
Research Team: Dr. Kerry Cawse-Nicholson, David Kelbe, Paul Romanczyk, Wei Yao (CIS - Ph.D.)

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.

Project Status:

The project is in its second year of a two year time allocation. In the last year, two major fieldwork campaigns have been carried out. The first was undertaken in Harvard Forest, Petersham, Massachusetts in August 2012 (Figure 3.22-44 shows some field photographs, Figure 3.22-45 shows some lidar data collected by NEON, and Figure 3.22-46 shows the intensity image from a terrestrial lidar scan). The second campaign took place in San Joaquin Experimental Reserve, California in June 2013 (Figure 3.22-47). Field data collected during each campaign included scans with a terrestrial laser scanner, leaf area index (LAI) measurements, tree mapping (including location, diameter at breast height (DBH), height, etc.) and spectral measurements. The NEON Fundamental Sentinel Unit (FSU) and Airborne Observatory Platform (AOP) groups collected data as well at both locations.

Figure 3.22-44: Hemispherical photographs of fieldwork sites in Harvard Forest.

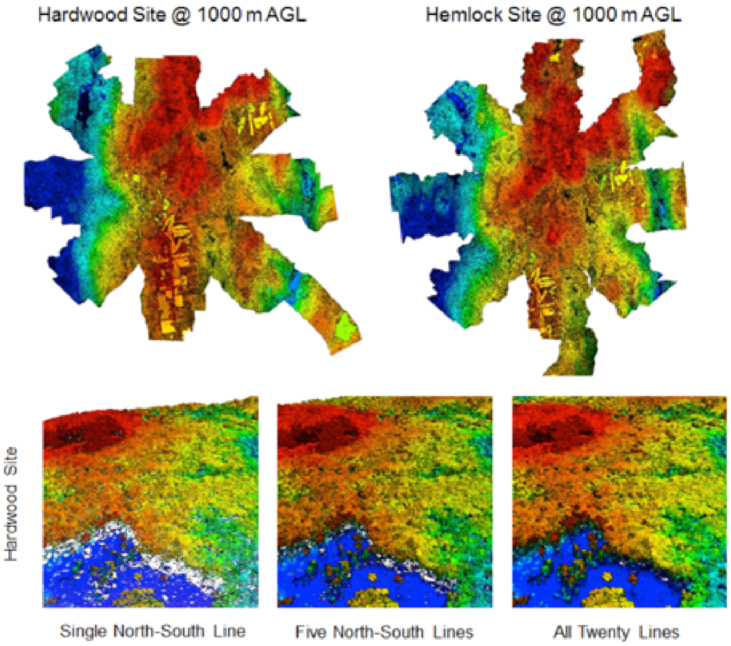


Figure 3.22-45: Lidar point clouds from the NEON August 2012 acquisition over Harvard Forest. The bottom image shows the returns from a single flight line (left), 5 multi-angle flight lines (center) and 20 multi-angle flight lines (right). (Image courtesy of Keith Krause, NEON.)

Figure 3.22-46: An intensity image from a terrestrial lidar scan taken in Harvard Forest during the field-work campaign in August 2012.

Figure 3.22-47: Photographs of fieldwork sites in San Joaquin Experimental Range (left) and Sierra National Forest (right).

The construction of realistic simulated scenes for input into the Digital Imaging and Remote Sensing Image Generation tool (DIRSIG) is an important focus of this project. Paul Romanczyk (CIS - PhD) has designed a small closed-canopy forest simulation based on real field data (such as tree species, height and diameter) from Harvard Forest. Wei Yao (CIS - PhD) is in the process of designing an oakland savannah simulation based on fieldwork in San Joaquin. Such datasets will be important for algorithm design and testing.

Individual contributions (also related to other synergistic projects):

David Kelbe (CIS - PhD) has created a workflow to derive certain ground-truth parameters from a single scan from a terrestrial laser scanner. These include tree location, DBH, etc., which are illustrated in Figure 3.22-48. These parameters may be used to inform synthetic scene building.

Paul Romanczyk (CIS - PhD) has evaluated the minimum geometry required for realistic scene construction in DIRSIG. Figure 3.22-49 shows a rendering of this DIRSIG scene which was constructed using field measurements from Harvard Forest. Paul found that twigs and leaf stems, while contributing nearly 75% of memory storage, do not significantly impact the waveform signal. Future work will include using this synthetic DIRSIG scene to develop products that will be applied to NEON airborne waveform lidar data, such as leaf area index (LAI).

Wei Yao (CIS - PhD) has begun analysis on the San Joaquin data collected by AVIRIS in June 2013. He will use synthetic scenes to evaluate the impact of spatial positioning of objects on large footprint pixels.

Kerry Cawse-Nicholson (CIS - post-doc) has implemented a Gaussian decomposition technique on real and synthetic waveforms. This preprocessing step enables understanding of specific interactions represented in the waveform. Using such preprocessed data, attenuation of the waveform through the canopy has been studied using synthetic tree models in DIRSIG, building on existing work.

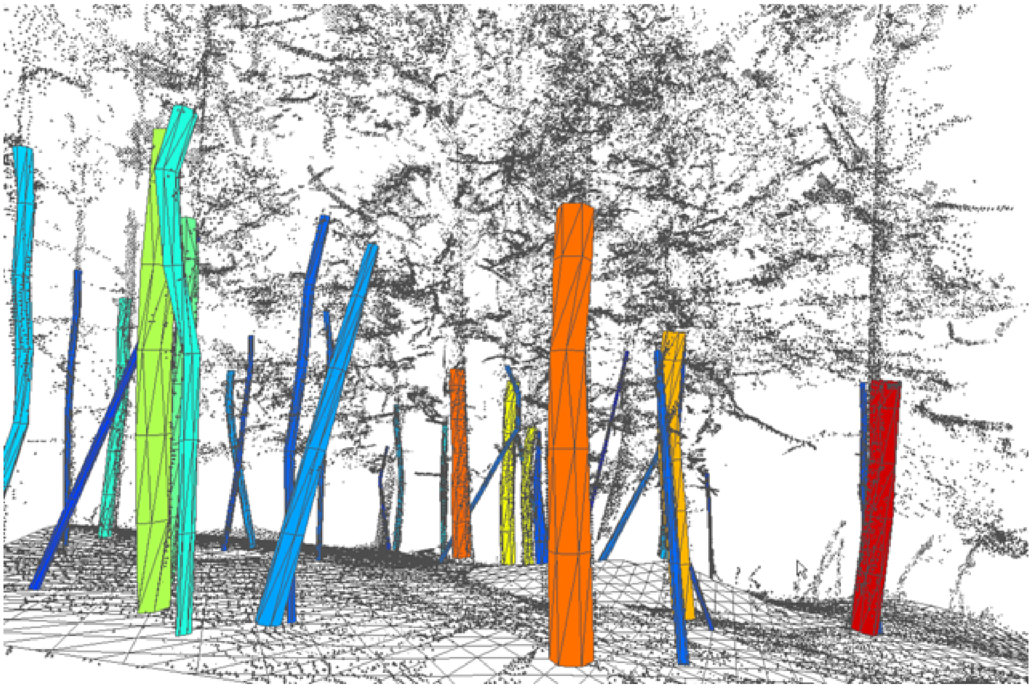


Figure 3.22-48: A digital elevation model (DEM) is approximated from a single terrestrial laser scan, and tree locations and diameters are approximated and represented by colored cylinders. These cylinders are stacked to adequately model taper and lean angle.

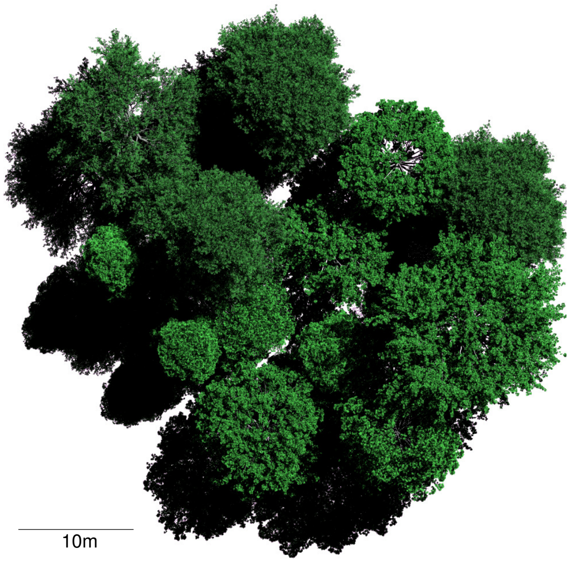


Figure 3.22-49: An RGB rendering of a realistic virtual forest scene, used for waveform LiDAR simulation in the DIRSIG simulation/modeling environment. The scene contains realistic red maple and red oak tree structures and spectra.

3.23 Consortium for 3D Innovation

Sponsor: National Science Foundation (NSF)
Principal Investigator: Dr. Jan van Aardt
Research Team: Dr. Carl Salvaggio, Dr. John Kerekes, Dr. David Messinger, Mike Richardson, Paul Romanczyk (CIS - Ph.D.), Madhurima Bandyopadhyay (CIS - Ph.D.), Katie Salvaggio (CIS - Ph.D.), Michael Harris (CIS - MS), Ming Zhang (CIS - MS), Jie Zhang (CIS - MS), and Noah Snavely (Cornell University)

Project Description:
The world of information is being transformed with the introduction of georeferenced visualization environments. A new imaging paradigm is emerging thanks to advances in imaging technology and photogrammetric processing algorithms. Instead of traditional vertical (ortho) or side view (oblique) photographs, fully 3 dimensional (3D) representations are possible enabling a user to fly, drive, or walk through a virtual world. This world is not just a simplified CAD representation of structures or a simulation, but rather a fully textured scene containing all of the visual and in some cases, non-visual information that is present in physical space. This facilitates the natural human visual processing of information in it's true context. In response to these challenges, RIT developed a new Innovation Ecosystem, the Consortium for 3D Innovation (C3I), built around the translation of cutting edge academic research in 3D photogrammetry and extraction of information from images into tools for rapid, automated production of high fidelity 3D virtual worlds. Faculty and students from RIT's Saunders School of Business have been conducting research into identifying lucrative markets and product concepts that utilize 3D visualization. Our commercial partners specialize in production and use of imagery or imagery derived information products. They include Exelis (formerly) ITT Geospatial Systems, leader in high end imagery collection and processing systems; Pictometry International, providers of high resolution imagery information products; and Lockheed-Martin, leader in integration of live, virtual, and constructive training products.

Project Status:
To date four PhD Imaging Science students (Katie Salvaggio; Madhurima Bandyopadhyay; David Kelbe; Paul Romanczyk), three MS Imaging Science students (Michael Harris; Ming Zhang; Jie Zhang), and five MBA Saunders School of Business students (Ramandeep Aulakh; Lusha Zhuang; Guillermo Alberto Valdez Sanchez; Dushyant Dhere; Andrew Puccio) have actively participated in and were funded by the NSF AIR C3I project. These students mainly have worked with three industry collaborators, namely Pictometry, ITT (now Exelis), and Lockheed-Martin, while also developing 3D algorithms that could potentially fit these companies' product portfolios. The students between them have produced algorithms, conference papers, submitted journal papers, and have a provisional patent in the development phases. The three MS students have defended their MS theses during summer-fall of 2012. Details of the research, specific to each industry collaborator, are described next.

Pictometry: In this part of the project RIT is working with Pictometry International to investigate the automated extraction of 3D building models from their proprietary oblique airborne imagery. Pictometry has a patented imaging system that acquires airborne imagery of the earth's surface from the four cardinal directions (north, east, south, and west) as well as directly above (nadir). Figure 3.23-50 shows example Pictometry imagery of the RIT campus that has been serving as an initial test case. Figure 3.23-51 shows the theoretical basis of the project, i.e., overlapping (stereo imagery) from which we can extract 3D building models.

Exelis: The results from the initial 3D workflow were encouraging; however, there was still a lot of information that is not being utilized in the process. The computer vision algorithms implemented in the workflow were designed for photo-tourism and internet photo mining. In these types of applications, the images can come from anywhere and therefore cameras vary and cameras are not necessarily well known. However, aerial imagery is collected as the aircraft flies and therefore there is a distinct order to the images, and it is taken with the same imaging modality, likely with a fixed focal length. In the case of the RIT WASP and ITT WAAS sensors, the cameras themselves are well known and can be modeled and the aircrafts are flown with a GPS/INS, which can be used to get the location and pointing information for each camera. The 3D workflow does not take advantage of any of this information, and while the reconstructions look good, they are in an arbitrary space such that building heights and distances have no real world meaning. It became necessary to adapt Bundler such that it could take input estimates for the camera matrices. This work was completed by David Nilosek (PhD) as part of a different project and has become known as Geo-Bundler. This is a modified version of Noah Snavely's (Cornell University collaborator) Bundler that can use GPS/IMU information as an initial estimate in the bundle adjustment instead of using the 5-point pose estimation algorithm implemented by Snavely. An example of a 3D point cloud, developed as part of this project for downtown Rochester, is shown in Figure 3.23-52. An example of a meshed 3D product is shown in Figure 3.23-53.

Lockheed-Martin: The development of three dimensional models from airborne remotely sensed imagery, that can be rendered in simulation environments for various visualization purposes, requires two primary activities: creation of the three-dimensional geometric models of the scene and proper identification and attribution of the materials on each facet of the extracted geometry. This MS project sought to make progress in the latter of these two tasks. The technical approach being developed seeks to use airborne imagery from both nadir and oblique perspectives to make these material identifications. Assuming the three-dimensional models have already been extracted, knowledge of which pixels in the scene are on which facets is available. This project attempted to use a traditional trained classifier model to make the correct identifications from the imagery. In this paradigm, training sets of data of known material properties are identified. Features are extracted from the imagery that provide best material separation between classes and are used to train a classification algorithm. New, unknown samples can then have the same features extracted from them and compared to the distribution of features from the training set and appropriate matches can be estimated.

Figure 3.23-50: Example oblique and nadir Pictometry imagery of the RIT campus.

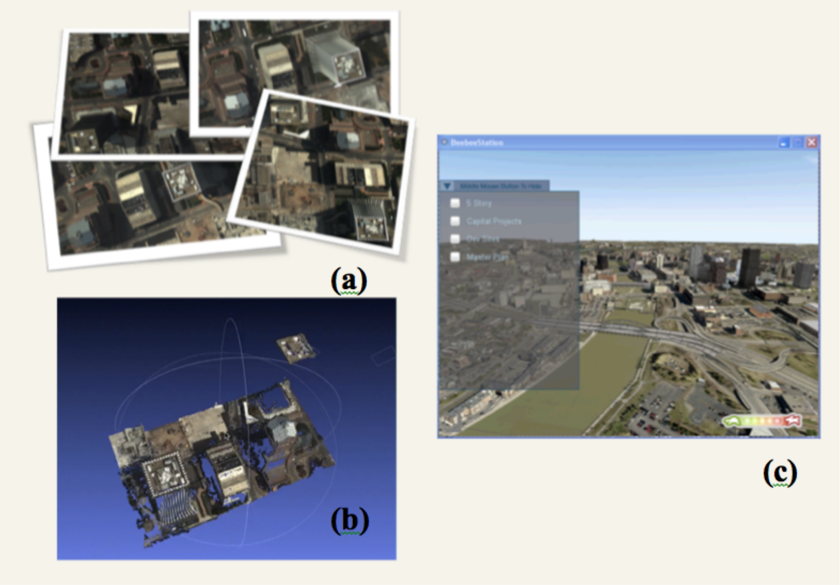


Figure 3.23-51: An overview of the theoretical basis of the project: (a) stereo imagery, from which (b) a 3D point cloud is extracted, followed by (c) a 3D building model rendering.

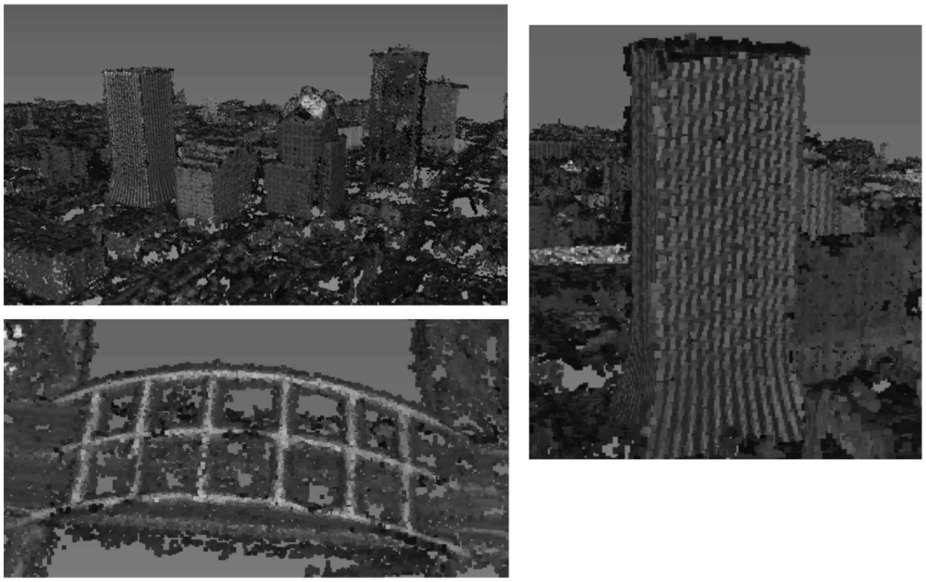


Figure 3.23-52: Various examples of sparse 3D x,y,z point clouds, extracted from imagery, for the downtown Rochester, NY region. Note that this is a very unique process; the next step involves extraction of the actual building objects to present 3D ”solid”, or facetized objects, e.g., those shown in rough form in Figure 3.23-53.

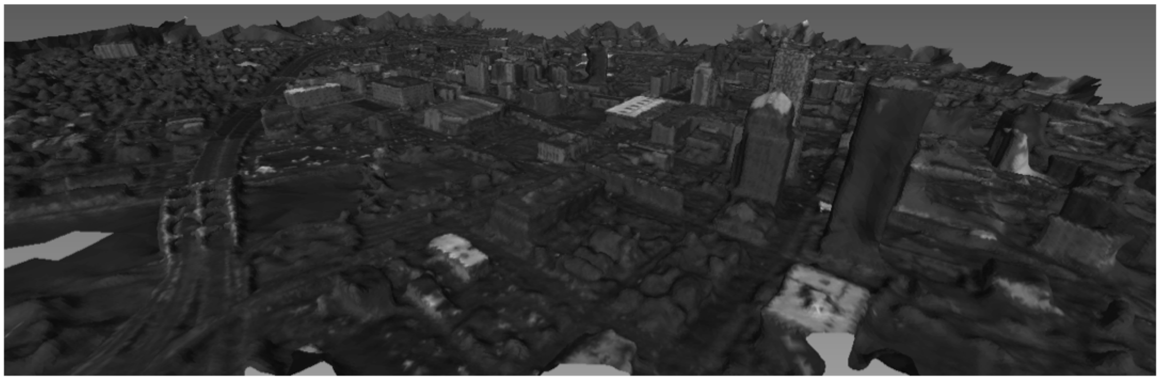


Figure 3.23-53: A rough form 3D "object model", extracted from the image-derived 3D point clouds, or x,y,z points. These buildings can now be cleaned and exported as a proper 3D city model.

3.24 HyspIRI - Investigating the impact of spatially-explicit sub-pixel structural variation on the assessment of vegetation structure from HyspIRI data

Sponsor: National Aeronautics and Space Administration (NASA)
Principal Investigator: Dr. Jan van Aardt
Research Team: Wei Yao (CIS - Ph.D.), Chris DeAngelis, Dr. Mike Gartley

Project Description:

The estimation of vegetation structural parameters, specifically in forest environments, has evolved from a spectral (multispectral to hyperspectral) to structural (radar to lidar) sensing modality space. All of these remote sensing methods have their respective advantages and disadvantages, e.g., lack of 3D characterization in the case of spectral sensors vs. the lack of large area coverage in the case of range or structural sensors. The goal of this project is to integrate the best aspects of the two worlds, high spectral but coarse spatial resolution remote sensing and fine-scale, detailed structural remote sensing, with an eye to regional-to-continental-to-global scale structure estimates. We are in the process of integrating fine-scale airborne and ground-based lidar assessments with the relatively coarse scale, but global HyspIRI imagery to improve HyspIRI-based vegetation structure and function assessments. We hypothesize that: 1. Fine-scale, within-pixel structural assessments can be used to improve our understanding of HyspIRI-based estimates of leaf area, leaf area index (LAI), and vegetation biomass; 2. From a systems perspective, the spatially explicit within-pixel structural variations are quantifiable when it comes to their impact on the HyspIRI system's response (point spread function); 3. An improved understanding of (1) and (2) will lead to proper calibration of HyspIRI-based vegetation structure estimates.

In short, our objectives are to (i) assess the structural variability within HyspIRI-scale hyperspectral pixels, (ii) link that variability to structural estimates, derived from HyspIRI, and (iii) improve those estimates via a defined calibration-validation effort. We argue that such an approach, where the impact of sub-pixel structural variation on HyspIRI scale structural estimates is assessed and quantified, will contribute to robust (consistent/precise) and accurate assessments of global vegetation structure. This will in turn aid our ability to properly model and map ecosystem structure and function.

Project Status:

The project is in the first of three years, with a starting date of January 1, 2013. Wei Yao (PhD) has collected field data from the National Ecological Observatory Network (NEON) Pacific Northwest site (Fresno, CA) with help from Dave Kelbe, Paul Romanczyk, Terence Nicholson, Ashley Miller, and Jan van Aardt. Figures 3.24-54, 3.24-55, and3.24-56 show examples of the data collection effort. Data include leaf area index (LAI) measurements, ground-based lidar scans, and spectra for 21 80x80m sites. These date are being processed and will be used for an initial study to investigate the impacts of leaf area variability on spectral signals at the 60m HyspIRI spatial scale. Results will be presented at the HyspIRI science workshop in Pasadena, CA, in October 2013.

Figure 3.24-54: The field team (left-to-right) of Ashley Miller (undergraduate), Paul Romanczyk (PhD), Wei Yao (PhD), and Dave Kelbe (PhD) setting up a Accupar logger to collect incident photosynthetic active radiation (PAR) in the Sierra Nevada mountain near Fresno, CA.

Figure 3.24-55: Graduate student Wei Yao (PhD) using an Accupar instrument to assess leaf area index (LAI) under a vegetation canopy at one of the field sites.

Figure 3.24-56: Dave Kelbe (PhD) using an in-house developed ground-based lidar system to collect detailed structural information for one of the study sites. Each lidar scans enables the team to construct a 3D representation of the surrounding area.

3.25 DDDAS for Object Tracking in Complex and Dynamic Environments (DOT-CODE)

Sponsor: Air Force Office of Scientific Research, DDDAS Program
Principal Investigator: Dr. Anthony Vodacek
Research Team: Dr. Matthew Hoffman (School of Mathematics), Burak Uzkent (CIS - PhD.), Bin Chen (CIS - Ph.D.), Dr. John Kerekes

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:
Our vehicle tracking approach is now Implementing a Gaussian Sum Filter. This type of particle filter allows us to adapt our tracking to important features such as road intersections. Another component of

our tracking work is incorporation of more complex turning models. An example of these improvements is visualized in Figure 3.25-57 and the resulting improvement in tracking performance is summarized in Figure 3.25-58. To leverage the adaptive sensor technology we have created adaptive sampling strategies for feature tracking that collect spectral data only for a specified small subset of pixels in the scene. Road and intersection detection and location are critical steps in our tracking process. To identify intersections efficiently within an image we are using the open-source OpenStreetMap road network for extracting intersection shape information. A local image search based on the OpenStreetMap intersections is used to register an image (with it's imprecise geolocation information and OpenStreetMap (Figure 3.25-59).

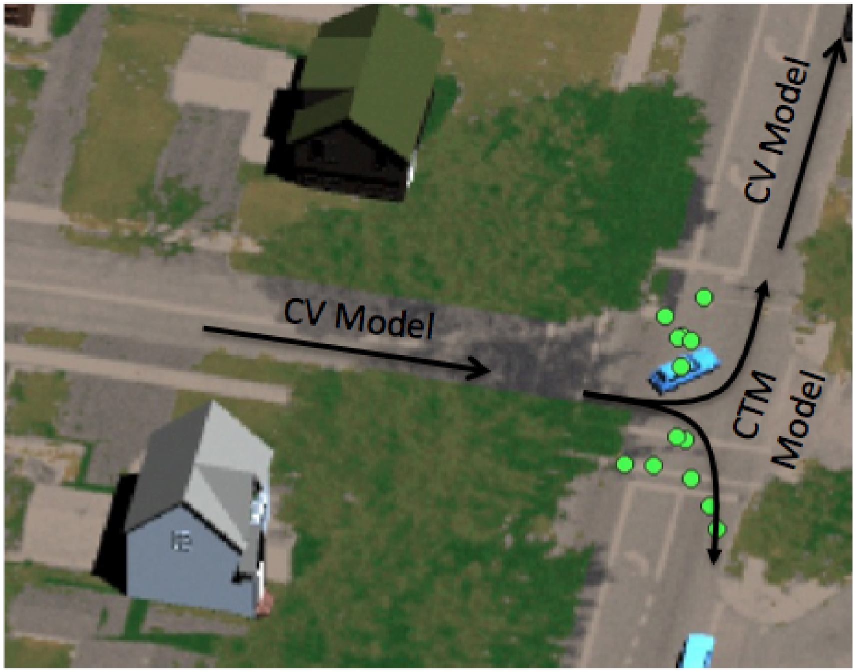


Figure 3.25-57: A T-shaped intersection in a DIRSIG scene. This is one frame of a 30 second scene with moving vehicles. The green dots indicate the center distribution of the components of a Gaussian Sum Filter for tracking the turning car. The spread of the Gaussian Sum provides tracking of the expected turn at the intersection to be either right or left.

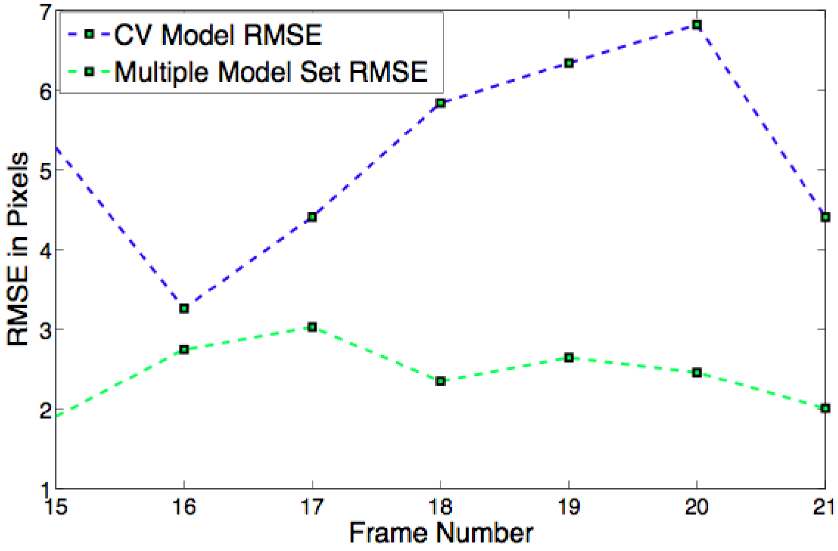


Figure 3.25-58: RMSE in pixels for predicted versus actual location of the vehicle while turning. A constant velocity model (blue) has higher error than a multiple model set (green) that adapts from a constant velocity model to a turning model when the vehicle is known to be approaching an intersection.

Figure 3.25-59: Image of a suburban area showing road sections and intersections identified in the image by leveraging Open Street Map data to prime a localized image search algorithm.

3.26 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: Dr. Anthony Vodacek
Research Team: Bikash Basnet (CIS - Ph.D.). US Collaborators at other universities: Dr. Bob Hecky (retired), Dr. Cindy Ebinger at the University of Rochester, and Dr. Chris Scholz at the University of Syracuse.

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 establishs 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 large-scale extraction of methane from Lake Kivu for electricity generation will have important consequences for development and conservation efforts in the region. The specific scientific field surveys and analyses made during this project 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:
Dr. Scholz analyzed seismic profiles of Lake Kivu sediments using sources with different frequencies to probe different depth into the lake bottom sediments. Major findings include clear signals of a long history of dramatic lake level change including a deepening of the lake by over 300 meters approximately 15,000 years ago, and since that deepening, turbidity flows have been an important phenomenon occurring in the lake. These turbidity flows have implications for safely engineering the extraction of methane gas from the lake by Rwanda and the DR Congo.

Dr. Hecky continued his analysis of Lake Kivu sediment cores and come to the important conclusion that Lake Kivu does have partial overturns, probably initiated by energetic turbidity flows, but the overturns do not extend to the deep waters and would not be the extreme hazard previously proposed in the case of a complete and sudden lake turnover. These partial overturns would however be catastrophic to the lake biota.

Dr. Ebinger installed a seismic array in northwest Rwanda. The array recorded many small earthquakes in the Rift Valley region and in the Virunga Volcanoes. The seismic data show active magma chambers beneath the two active volcanoes, Nyamulagira and Nyiragongo, as well as Karisimbi. The other Virunga Volcanoes do not have any signal of magma activity. This finding brings important information for the development of geothermal power by Rwanda.

At RIT we have continued our remote sensing analysis of regional land cover change. Some new results include the identification of a strong signal of urbanization across Rwanda between 2001 and 2010 that is interpreted to be a consequence of government policies to replace natural roofing types with highly reflective metal roofs and confusing the classifier, rather than a true change in urbanized area. We also gained a unique view of the region from a low-resolution declassified Corona Project image from August 21, 1964. Although is is somewhat limited by cloud cover, this image extends our satellite record back another decade before the initial Landsat image of the region. The Corona image is interpreted to show very large areas of forest loss between 1964 and the beginning of the Landsat data record. The most obvious areas of significant forest loss are in the highland areas in Burundi and the DRC to either side of Lake Tanganyika (Figure 3.26-61).

Figure 3.26-60: The Kilindi research vessel was brought to Lake Kivu under this project to enable the seismic profiling and sediment coring work.

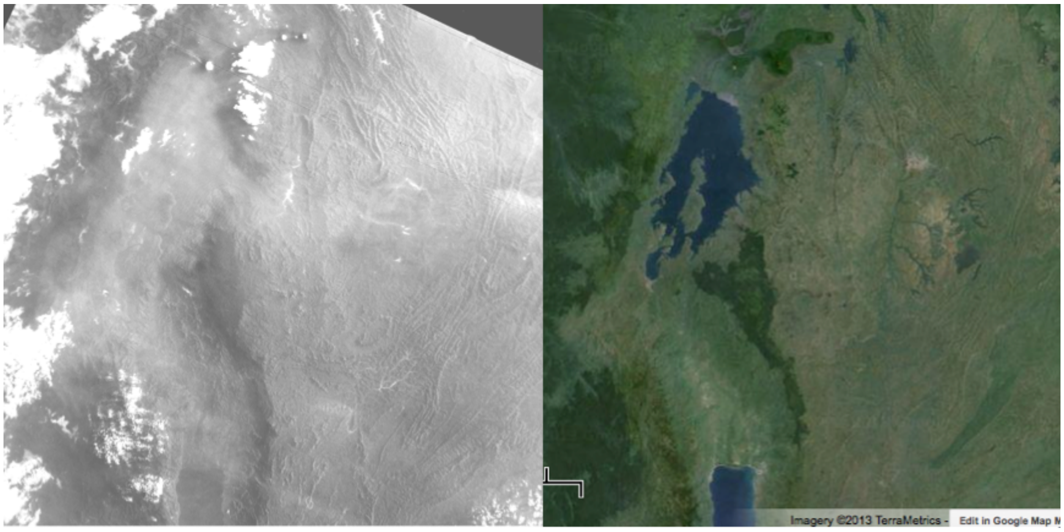


Figure 3.26-61: Corona Project image (mapping camera) from August 21, 1964 (left) and for comparison, a Google Maps image of the same region. Loss of forest since 1964 is interpreted for a number of sites in the region.

3.27 Promoting spatial thinking in natural resource management through community mapping

Sponsor: United Kingdom Department of International Development and Rwanda Ministry of Education Innovation for Education Program
Principal Investigator: Dr. Anthony Vodacek
Research Team:Dr. Brian Tomaszewski, Bikash Basnet (CIS - Ph.D.), Nick Holt (NSF REU student). Key Rwandan collaborators: Dr. Gaspard Rwanyiziri and Ernest Uwayezu at the Centre for GIS and Remote Sensing at the University of Rwanda (CGIS) and Chrysos Sehene and Angelo Kwisanga Businge at the Rwanda Environmental Conservation Organization (RECOR)

Project Description:
The development of spatial thinking skills is significantly under-represented in Rwandan secondary education. The project address this core challenge through natural resource mapping projects by Rwandan students around their schools in Southern Province. Direct training of teachers will enable demonstration projects with secondary school students. By mapping natural resources via free and open source technologies, students will learn accountability & empowerment and address climate change and environment issues, while our emphasis on recruitment of under-served students will foster inclusive education, where an emphasis on spatial thinking skills for problem solving will ultimately promote effective teaching and learning, skills development and use of appropriate technologies in education for secondary school-level students and teachers. The approach is new in that we are making a particular emphasis on (1) Free and Open Source Software (FOSS) vs. commercial software, (2) empowerment of students to become community advocates; and (3) looking at how FOSS can be used to developing spatial thinking skills. To the best of our knowledge, the approach has not been piloted in Rwanda. The innovation will empower young Rwandans with lifelong conceptual skills to solve and reason about problems spatially and will provide technical skills to benefit both students and teachers.

Project Status:

In summer 2013 we had our NSF REU student, Nick Holt, create prototype mapping software for Android tablet computers. His prototype has the basic functionality to map points, lines, and polygons on a basemap of the site where the device is located, by accessing the built-in GPS (Figure 3.27-62). To track the efficacy of our curriculum, we are using a test of spatial think ability to track student's performance over time. The finalized test was given as planned, to 222 students in mid-July by Co-PI Tomaszewski. Approximately seventy-five students each from our two target schools and a control school took the test. Initial analysis of the baseline results, using statistical and graphical tools, show significant differences in performance among the schools and by gender (Figure 3.27-63). Working with our Rwandan partners, we have begun teacher training exercises to familiarize the teachers with mapping fundamentals and with the operation of the tablets (Figure 3.27-64). We are working toward placing the tablets in the hands of the students so that they can use and acquire spatial thinking skills to map their local environment.

Figure 3.27-62: Visual prototype of the tablet mapping application.

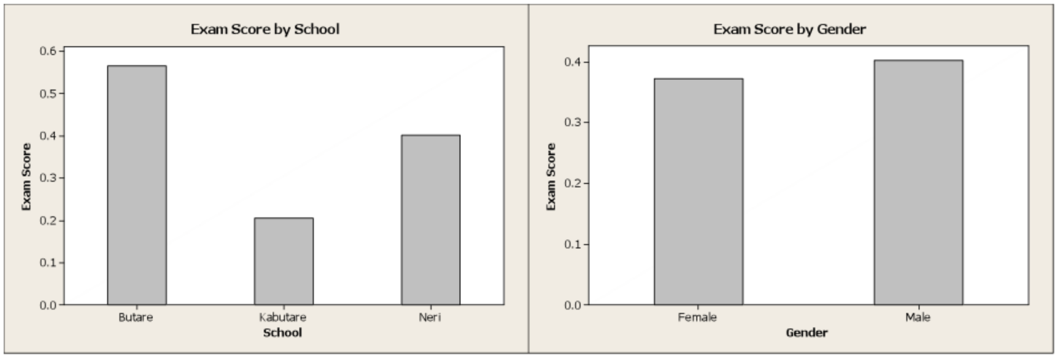


Figure 3.27-63: Our baseline testing found statistically significant differences in spatial thinking test between schools and between gender.

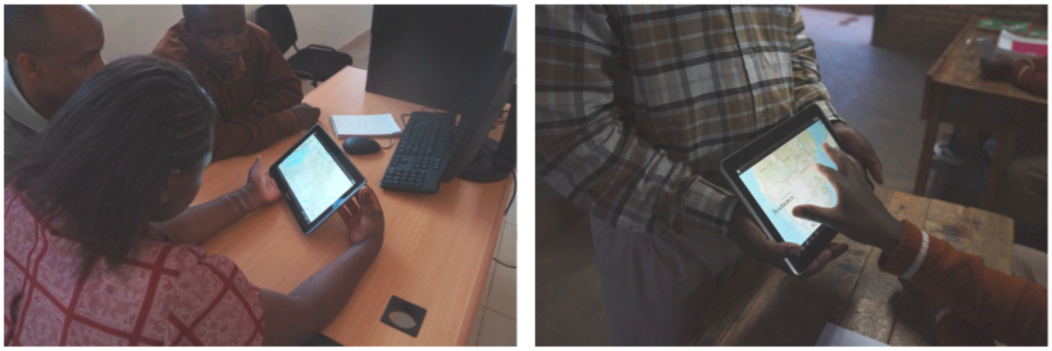


Figure 3.27-64: We have begun introducing teachers and students to the capabilities of the tablet computers.

4 Publications During This Period

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[4] D. Simmons, "Hyperspectral monitoring of chemically sensitive plant sentinels," M.S. thesis, Rochester Institute of Technology, College of Science, Center for Imaging Science, Rochester, New York, United States, 2013.

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