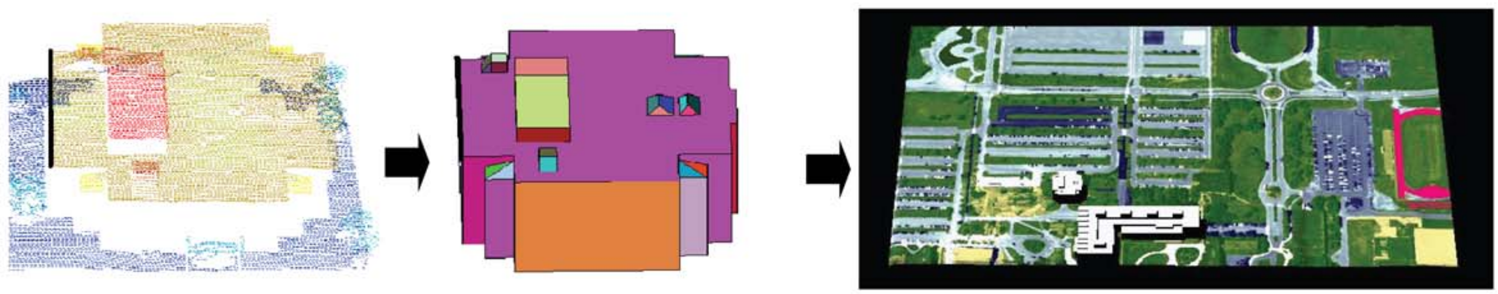
Rochester Institute of Technology

Digital Imaging and Remote Sensing Laboratory

Annual Report for the 2006 Academic Year
(July 1, 2006 – June 30, 2007)
of the
Frederick & Anna B. Wiedman Professor
on the
Activities of the Digital Imaging and Remote Sensing Laboratory
Prepared by Dr. John R. Schott



2D Projection of LIDAR Data → LIDAR Derived CAD Model → DIRSIG rendering of RIT campus derived from remotely sensed imagery and library databases

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R·I·T

1.0 Forward

When I look back on this year, it is with a sigh of relief and a heart full of thanks. The relief is over the final release of the second edition of my book, Remote Sensing: The Image Chain Approach. This project which included the expansion from 394 to 666 pages and 10 to 14 chapters was a major multiyear effort squeezed on top of my normal commitments. The thanks is for all the help I had both inside DIRS and from the many professionals I leaned on across the community for materials, insight and help with reviews. The biggest thanks goes to the DIRS team who have helped both directly and indirectly. The thanks for the direct help on graphics, illustration, organization, etc. are acknowledged in the book and, while I reiterate them here, I really want to emphasize the often unacknowledged help of all the staff who helped fill in for my absence or distraction during this period.

The DIRS team has grown enormously in the last few years not so much in number but in capabilities and accomplishments many of which you will see reflected in these pages. We were particularly pleased this year to have Dr. David Messinger promoted to Research Faculty in acknowledgement of his growing role in publications, grantsmanship and student mentoring. Dave's membership brings the number of faculty in DIRS to five and helps spread the student mentoring, program development and management load across a larger more diverse team. It is this diversity of programs directions, sponsors and student opportunities that I encourage you to examine as you peruse these pages. We are striving to maintain our focus on quantitative analytical (physics based) remote sensing while exploring a broad range of sensing modalities and mission driven applications. The increased number of principle investigators, both among the faculty and staff, is enabling this increased diversification. Many of the staff are participating in program development and more direct student mentoring allowing us to not only respond more effectively to sponsors needs but also to provide a more enriching experience for our students.

In stepping up to help me over these last few years this team has gone beyond stepping up and truly has stepped out both as individuals and as a team. I believe we are on the brink of taking the DIRS research enterprise to a new level reflecting the diversity of talents we have brought together while maintaining, I hope, the very close interconnected team based approach built on shared goals and values.

The pages which follow offer a glimpse into the people and programs that made up the DIRS Laboratory over this past year. The program descriptions are only intended to give you a glimpse into this activity and we invite you to contact us or follow the literature references for a more in depth treatment of any topic. The staff to whom I owe so much this year, as always, are introduced in Section 2 of this report. Also in Section 2, we introduce our raison d'art, the students who sometimes frustrate and more often inspire our collective enterprise.

In closing, I want to acknowledge once again the generosity of Frederick Wiedman Jr. whose gifts to the Institute in honor of his parents Frederick and Anna B. Wiedman endowed the chaired professorship I hold. The income from this endowment enables us to occasionally fund a small amount of exploratory research until we can identify external support for these studies. The facility/process modeling study described in Section 4.2 exemplifies this process where the Wiedman endowment is helping to support one of the students' who is working to explore this new direction for the DIRS group. At many points during the year I stop to acknowledge the help that Mr. Wiedman's generosity has enabled and this year in particular it has been focused on this exciting new project.

As ever my thanks to our sponsors for your confidence in us and the DIRS faculty, staff and students for making this another very successful year.

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2.0 DIRS Group

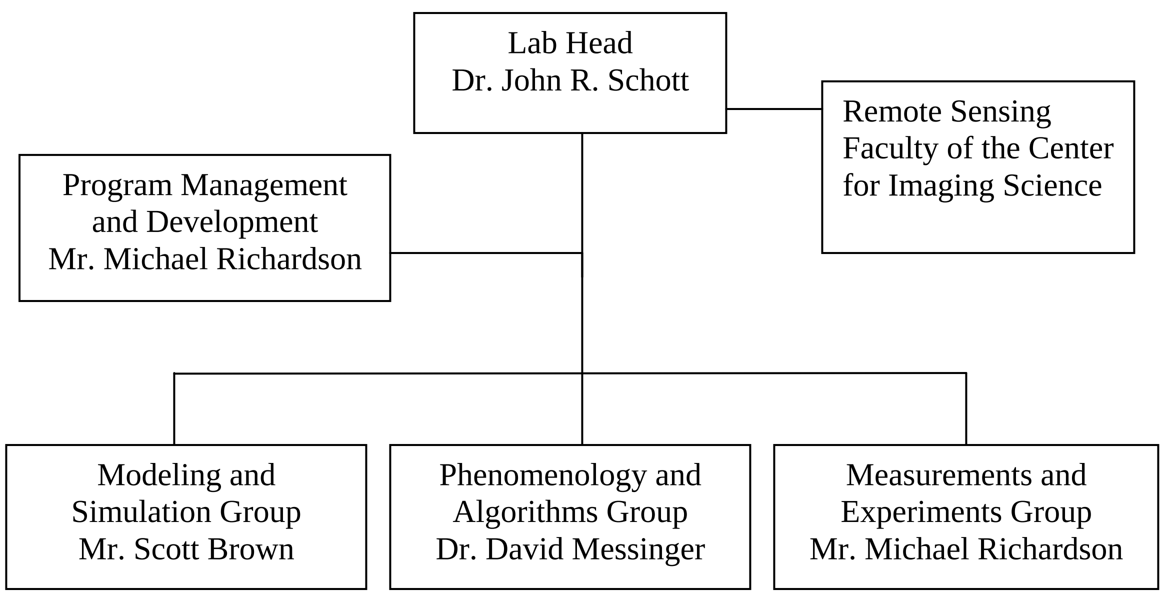
2.1 Background

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 and the education of students who will continue this work for government agencies and private industry.

The DIRS group is made up of faculty and research staff working with over 30 students ranging from the Baccalaureate through Doctoral level. Most students are degree candidates in Imaging Science, but students from other departments, such as Engineering and Physics, are often part of the student population supporting our research initiatives. This year also saw the inclusion of several high school interns who were provided the opportunity to participate in research projects and learn more about imaging science.

2.2 Laboratory Organization

The DIRS Lab is managed using a matrix approach where faculty and senior research staff manage programs to generate research results, student thesis and meet sponsor requirements. The research staff, organized into three overlapping groups managed by group leaders, supports the needs of the research programs.



The Laboratory of Imaging Algorithms and Systems (LIAS) is a “sister” laboratory within the Center for Imaging Science which also conducts remote sensing research focused on airborne imaging system development and user applications. DIRS and LIAS have several joint endeavors.

2.3 DIRS Personnel

The Faculty Team

Dr. Carl Salvaggio
Associate Professor
Research Interests:
- Novel techniques and devices for optical property measurement
- Applied image processing and algorithm development
- Image simulation and modeling

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Dr. John R. Schott
Professor and DIRS Laboratory Head
Research Interests:
- Hyperspectral data analysis and algorithm development
- Multi and hyperspectral instrument development
- Synthetic scene generation

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Dr. John Kerekes
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- Image chain modeling and parametric analysis

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Dr. Anthony Vodacek
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- Forest fire detection and monitoring
- Active and passive sensing of water quality

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Dr. David Messinger
Research Faculty
Research Interests:
- Image processing and algorithm research

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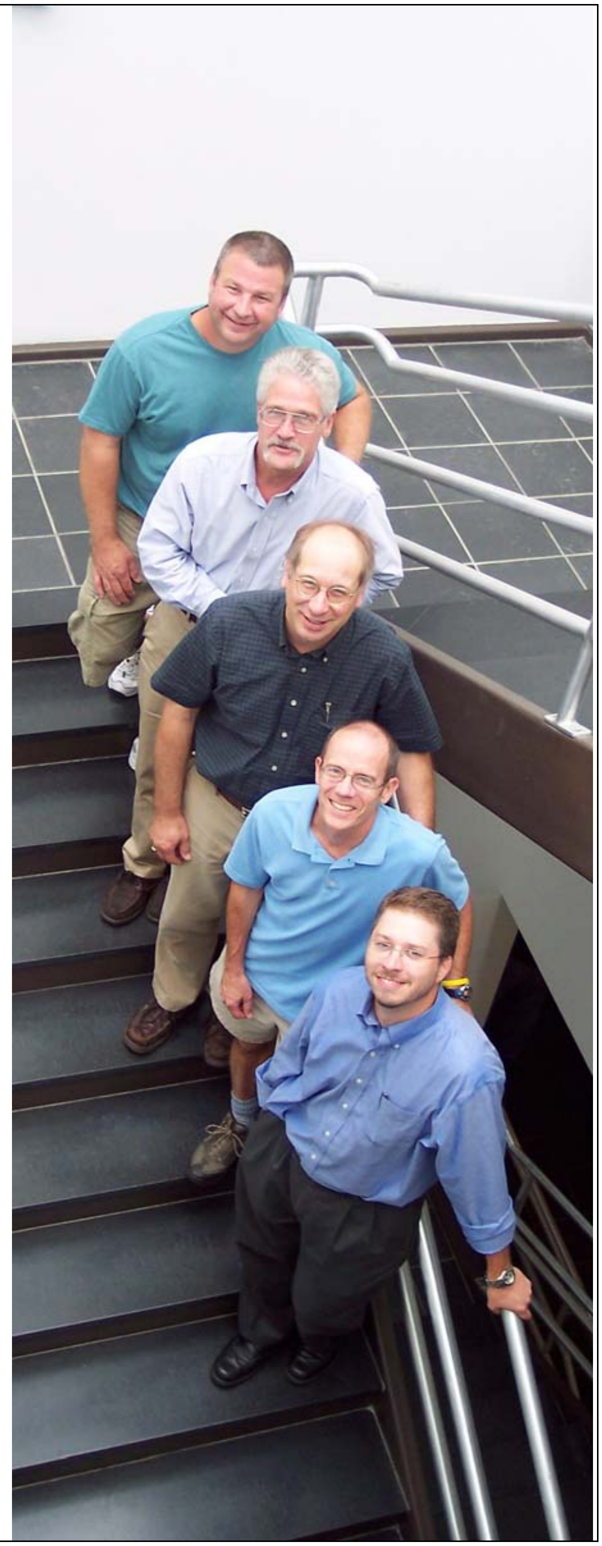

The Research Staff

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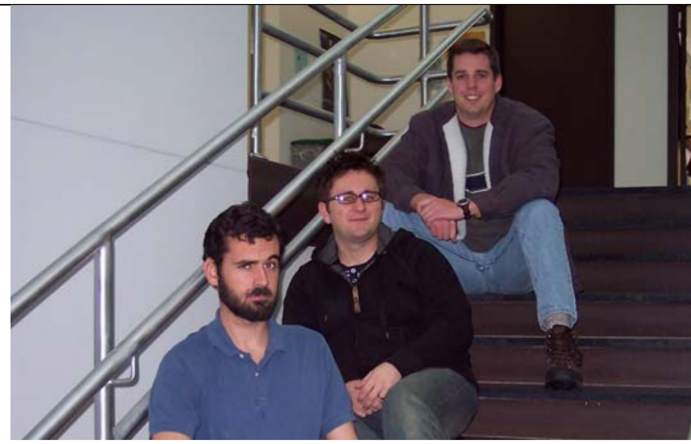

ALGORITHMS AND PHENOMENOLOGY

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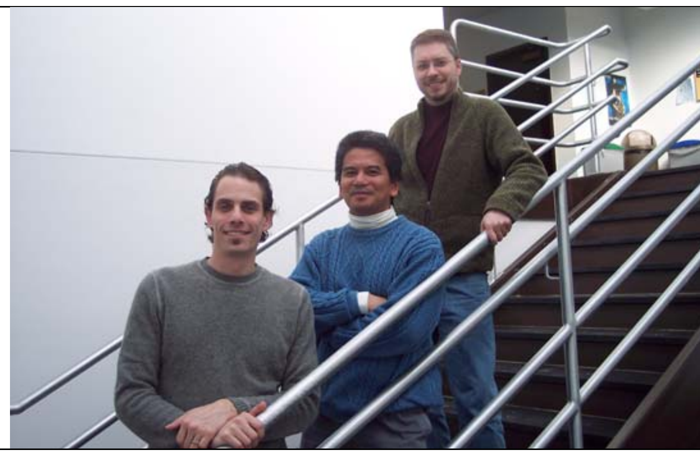

MEASUREMENTS AND EXPERIMENTS

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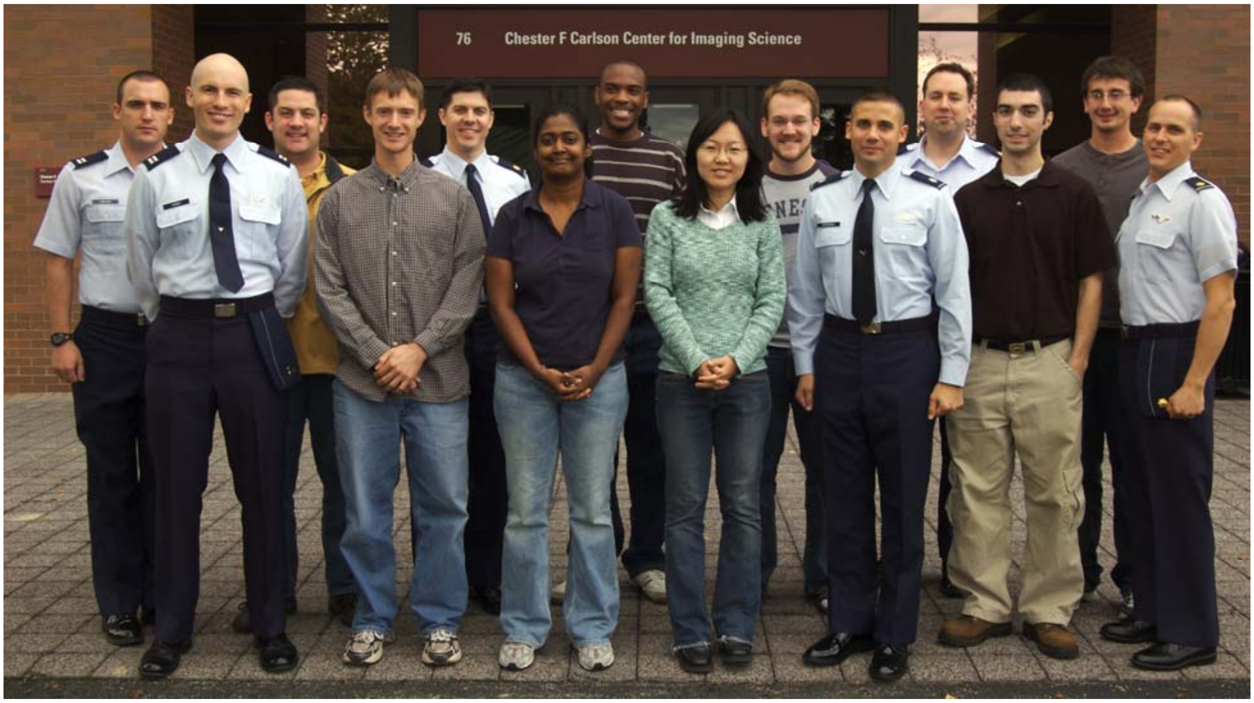
Cindy Schultz - Staff Assistant Staff Support (585) 475-5508 schultz@cis.rit.edu	

The Student Teams

DIRS Masters' students



DIRS Ph.D. students

United States Air Force Officers in our graduate program (summer 2007)

The DIRS Student Team

Andy Adams
James Albano
May Arsenovic
Brent Bartlett
Dan Blevins
Marvin Boonmee
Jason Casey
Pierre Chouinard
Adam Cisz
Jake Clements
Brian Daniel
Chabitha Devaraj
Manny Ferdinandus
Kyle Foster
Mike Foster
Adam Goodenough
Jason Hamel
Josh Huber
Marek Jakubowski
Scott Klempner
Steve Lach
Yan Li
Ying Li
Domenic Luisi
Sharah Naas
Jim Shell
Danielle Simmons
Natalie Sinisgalli
Alvin Spivey
Kristen Strackerjan
Don Taylor
Zhen Wang
Jason Ward
Seth Weith-Glushko
Yushan Zhu

3.0 Research Project Summaries

This section provides a brief insight into each of the projects. For more information, please contact the faculty and staff working on the project.

3.1 ONR MURI

Sponsor(s): Office of Naval Research (ONR)

Project Description: Hyperspectral data is becoming a critical tool for military planners. The capture of fine spectral information enables the generation of information products which could not be produced using traditional imaging means. The challenge facing hyperspectral technology, as an operational capability, is with conversion of the raw sensor data into a useful information product that is accurate and reliable. Traditional approaches for processing hyperspectral data have largely focused on the use of statistical tools to process a hypercube, with little regard for other data that may describe the physical phenomena under which the data were collected. The long-term goal of this project is to develop a new generation of hyperspectral processing algorithms that take advantage of the underlying physics of a scene while utilizing statistical processing techniques to generate valuable information products.

Project Status: The RIT MURI team (RIT, University of California Irvine, Cornell University) initiated research under this MURI in May 2001 and over this period, there has been substantial research progress in validating the utility of physics-based algorithmic approaches. This MURI has been a catalyst for the research team to be awarded additional research support from other sponsors. The research results generated have been shared with the hyperspectral community through the generation of over 50 peer reviewed journal articles, presentations at technical conferences, and published Masters and Ph.D. theses. This project has supported over 15 graduate students, many of whom have graduated or are about to graduate, and will be taking positions in direct support of the defense and intelligence community. The MURI project ended on September 30, 2007.

3.1.1 Longwave Temperature/Emissivity Separation and Atmospheric Compensation

Research Team: Marvin Boonmee (Ph.D. student), John Schott, David Messinger

Project Scope: This project seeks to develop an algorithmic approach to the problem of temperature / emissivity separation effects in longwave infrared hyperspectral imagery. Along with this task, atmospheric effects in the imagery will be compensated for.

Project Status: Much progress has been made on this research and a unique methodology for atmospheric compensation and temperature / emissivity separation in LWIR hyperspectral imagery has been developed. The algorithm is currently undergoing extensive testing on both simulated and real imagery. The method developed combines techniques using in-scene information as well as model-based information into an optimization framework. Using synthetic data, the algorithm has shown the ability to determine the land surface temperature to within approximately 1 – 2 K and the surface emissivity to within 1-2 %. The algorithm has been demonstrated to be robust to both sensor noise and spectral miscalibration effects.

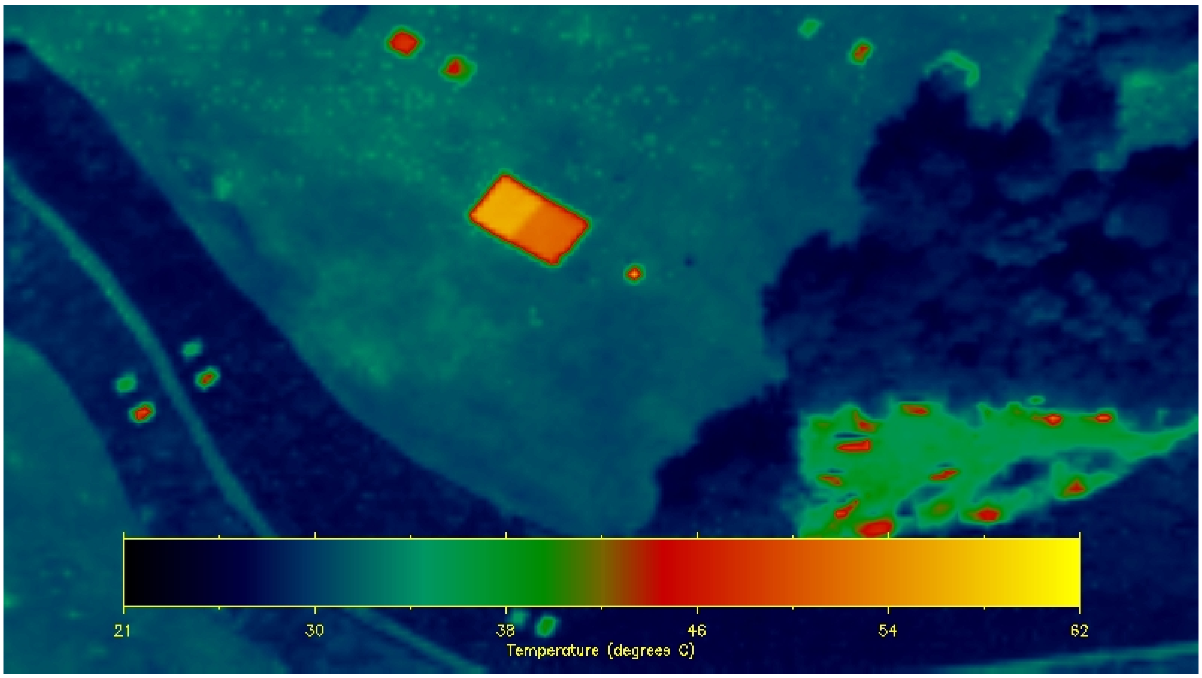


Figure 3.1.1-1: Estimated surface temperature for an image collected with the SEBASS LWIR hyperspectral sensor over Camp Eastman in Rochester, NY during the MegaCollect experiment conducted in June 2004. Color indicates retrieved temperature as shown in the color bar. The large objects in the center of the scene are calibration panels. The left panel is black (and thus has a higher temperature) and the right panel is gray. The small object just to the right of the panels is a heated target. Retrieved temperatures are accurate to within approximately 1-2 K.

Figure 3.1.1-1 shows results from applying the algorithm to a scene collected over Camp Eastman in Rochester, NY in June 2004 with the SEBASS hyperspectral sensor. The large calibration panels in the center of the image were instrumented to measure their temperature providing a quantitative measure of the algorithm accuracy. Here, the temperatures were retrieved to within 1-2 K. Other objects visible in the scene include a small heated target, test panels on the hillside and in the field, and the vehicles in the parking lot. Note also that small temperature fluctuations in the grass field are retrieved using this method.

3.1.2 In-water Radiative Transfer Modeling using Photon Mapping and Model-based In-water Target Detection

Research Team: Adam Goodenough (Ph.D. student), Rolando Raqueño, Michael Bellandi (B.S. student), Scott Brown, John Schott

Task Scope: The objective of this task is to create synthetic scenes of multiple scattering dominant waters such as those found in littoral zones. A general, efficient solution for complex radiative transfer is being developed based on Monte Carlo ray tracing. This task incorporates significant changes and improvements to RIT's DIRSIG tool.

Task Status: Significant progress has been made with the Photon-Mapping model to simulate complex hydrologic radiative transfer. This past year's activities were focused on baseline validation of the technique, data architecture design of simulation elements and their behavior, and integration of key routines into the DIRSIG environment. The validation of the technique compared several radiometric case studies described in the seminal paper by Mobley et al. (1993). Each of these cases was simulated showing very good agreement with the different cases established by the comparative study. In cases where there were significant discrepancies, it is believed that the model implemented in DIRSIG represented a more sophisticated treatment of the problem. Comparisons were also demonstrated against Carder et al. (2005) and Zaneveld et al. (2001) where spatial obscuration and surface effects were simulated showing agreement to the modification to the light field under these conditions. In order to achieve the correct radiometry of these simulations, substantial modifications have been made to the DIRSIG simulation framework to develop a more general and flexible representation of radiometric concepts/elements and their interaction across the different media encountered in the littoral environment (see Figure 3.1.2-1). A flexible interface to the tools provides future users with a library of extensible, built-in optical property models and high-level control over computation parameters.

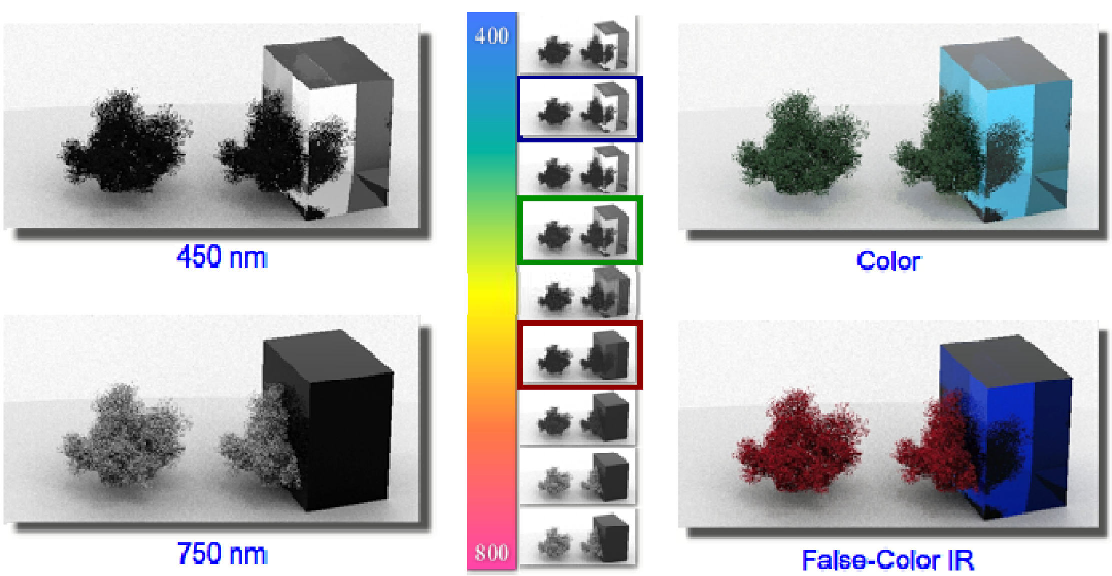


Figure 3.1.2-1 Simulations of a plant in and out of a freestanding block of water.

Because the utility of the DIRSIG-Photon Mapping simulation environment is meant to be applied across different spatial scales, a "surface sampler library" and novel BRDF integration techniques have been implemented to provide the ability to adaptively sample radiometric contributions to a scene. These tools have already been exploited in at least two other doctoral projects on unrelated topics. In addition to these radiometric improvements, a preliminary scheme to address spatial scales of wave effects has been implemented to provide the necessary fidelity in addressing a very crucial dimension of littoral modeling. In addition to follow on work that will validate the radiometry of the DIRSIG-Photon Mapping for more complex scenarios, the tools developed from this effort will play a key role in a recently awarded Intelligence Community doctoral fellowship studying the microscale radiometry of surfaces and participating media.

3.1.3 Suspended Sediment Modeling

Research Team: Jason Hamel (Masters' student), Donald Taylor (Masters' student), Minsu Kim (Cornell University), Rolando Raqueño

Task Scope: Quantitative hyperspectral remote sensing of coastal and inland water resources has been hindered by inadequate performance of atmospheric compensation methods. The techniques used for oceanic conditions operate on the premise that there is negligible water leaving radiance in the near infrared region (NIR 750-950 [nm]) and any sensor reaching radiance is mainly due to the atmosphere. The problem stems from the abundance of suspended materials from anthropogenic and benthic sources in Case II waters not usually observed in the deep ocean. The scattering effects of suspended sediments greatly affect the water leaving radiance in the visible to the NIR region resulting in overestimation of the atmospheric contribution to the radiance reaching the sensor. In order to adapt current atmospheric compensation methodologies, a means of estimating the water leaving radiance in the NIR region needs to be devised. This work describes a set of numerical modeling tools that have been integrated to predict optical properties of suspended minerals and their effects on the water volume spectral reflectance.

Task Status: The suspended sediment modeling work has been a cornerstone work in its own right as well as a foundation for the atmospheric compensation work. To date, the sources of IOPs for constituents (particularly suspended sediments) do not exist in the near-IR region (800-950) because of the limitations of instrumentation and the current assumption that the returns in those regions for Case I waters are negligible. As highlighted by emerging works presented at Ocean Optics 2006, the application of atmospheric compensation techniques to Case II waters are being hindered by the lack of characterizations of previously ignored constituent (suspended sediment) in a wavelength region where in-situ and lab measurements are difficult. The modeling that resulted from the linkages between the OOPS algorithm and HYDROLIGHT produced plausible results that underscores the importance of particle size distribution, scattering phase function, and number density as major considerations in optically characterizing turbid Case II waters. The competing effects of these properties on the final radiometry can only be elucidated by modeling methods used in this research. The Mie scattering codes used in these analyses provided initial estimates that established idealized trends of particle parameter effects on the overall inherent optical properties, but have not been established as sufficiently optimum. While the current results are very telling and informative, they need to be validated either through laboratory experiments or application of more sophisticated scattering codes that are better suited for the wide size regimes encompassed by the current Mie code and more realistic particle-shape scenarios. The merit and inadequacy of this work is illustrated by its comparison to the long standing Petzold functions show in Figure 3.1.3-1. While there is general agreement in shape of the scattering phase function, the "spherical" assumption of the Mie code leads to artifacts that are not found in natural waters of realistic distributions.

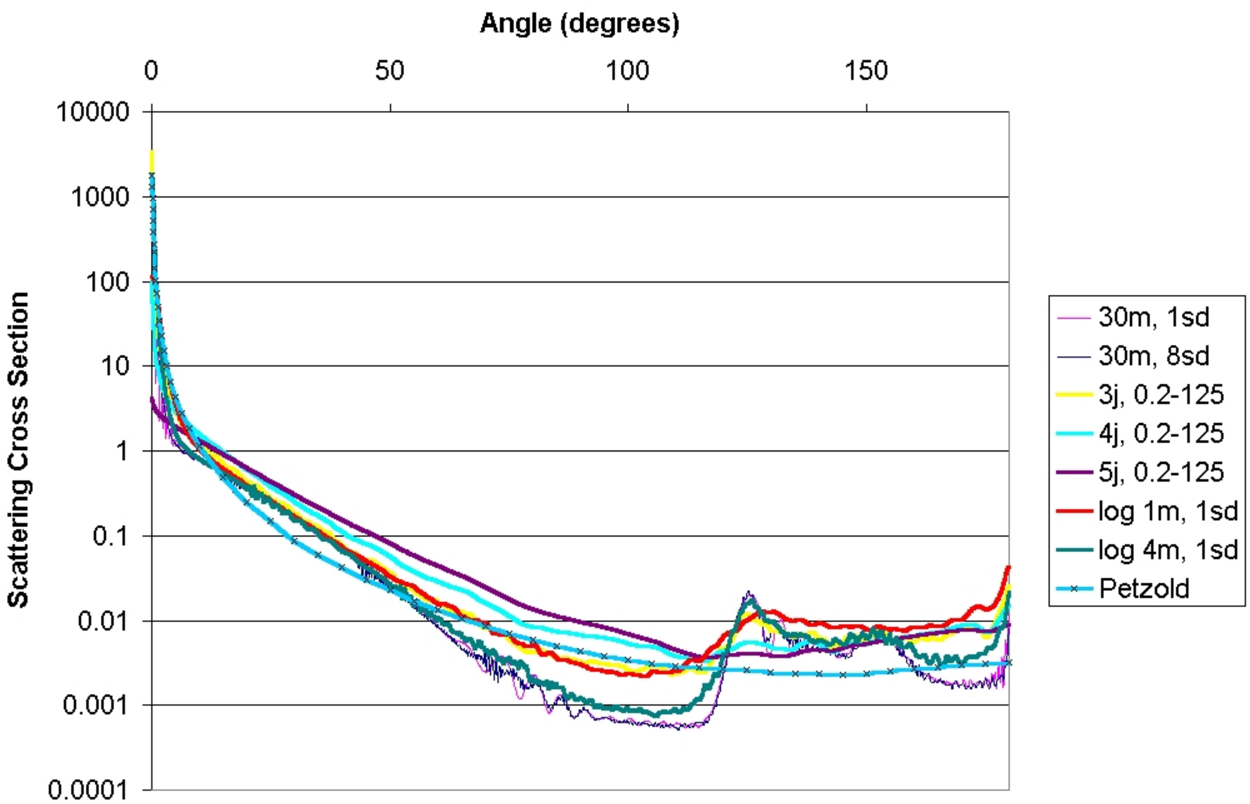


Figure 3.1.3-1: Phase functions at 500nm for a variety of phase functions. Phase functions displayed in this plot: Gaussian with 30 micron mean and 1 or 8 standard deviation width; Junge from 0.2-125 microns with 3,4 or 5 Junge coefficient; Log-Normal with 1 or 4 micron mean and 1 standard deviation width; and the Petzold phase function as listed in Light and Water by Mobley.

Another trend that arose when examining the output from the Mie scattering code concerned the nature of particle scattering and the effect it has on the final apparent reflectance of a water body. As many researchers have found over the years, scattering tends to be dominated by smaller particles whose size is closer to the wavelength of light being scattered. Thus, when examining the scattering phase functions of various particle distributions, smaller particles scatter a larger percentage of their light in the 90-180 degree direction. This trend is again seen in the back scattering ratios generated during this research (Figure 3.1.3-2). These same trends are not observed in the final apparent reflectance of the water body though (Figure 3.1.3-3). The complication leading to this result is apparent when one examines the scatter cross-sections of the various particle size distributions (Figure3.1.3- 4). As shown in the plot, while larger particles might send a smaller percentage of the light backwards compared to smaller particles, they have a much larger area for interaction with photons. The end result can be a larger amount of total light being scattered into the backwards direction than expected from previously published work.

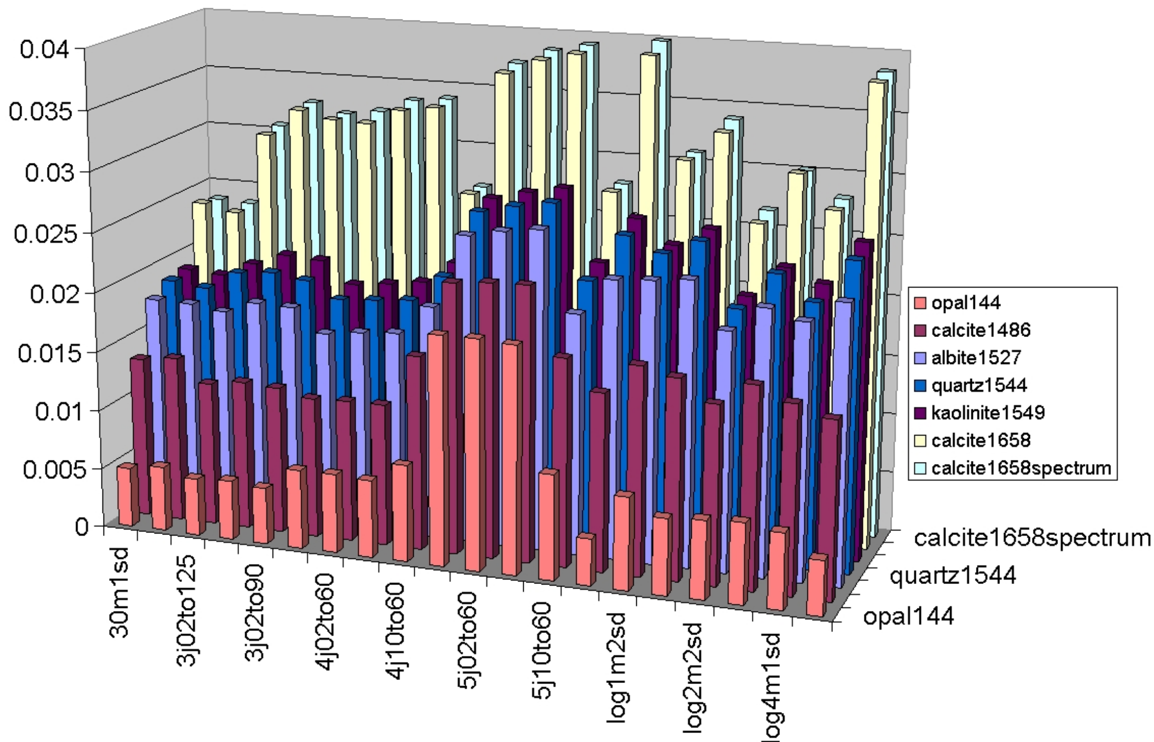


Figure 3.1.3-2: Back scatter ratios at 550nm for various mineral and particle size distributions.

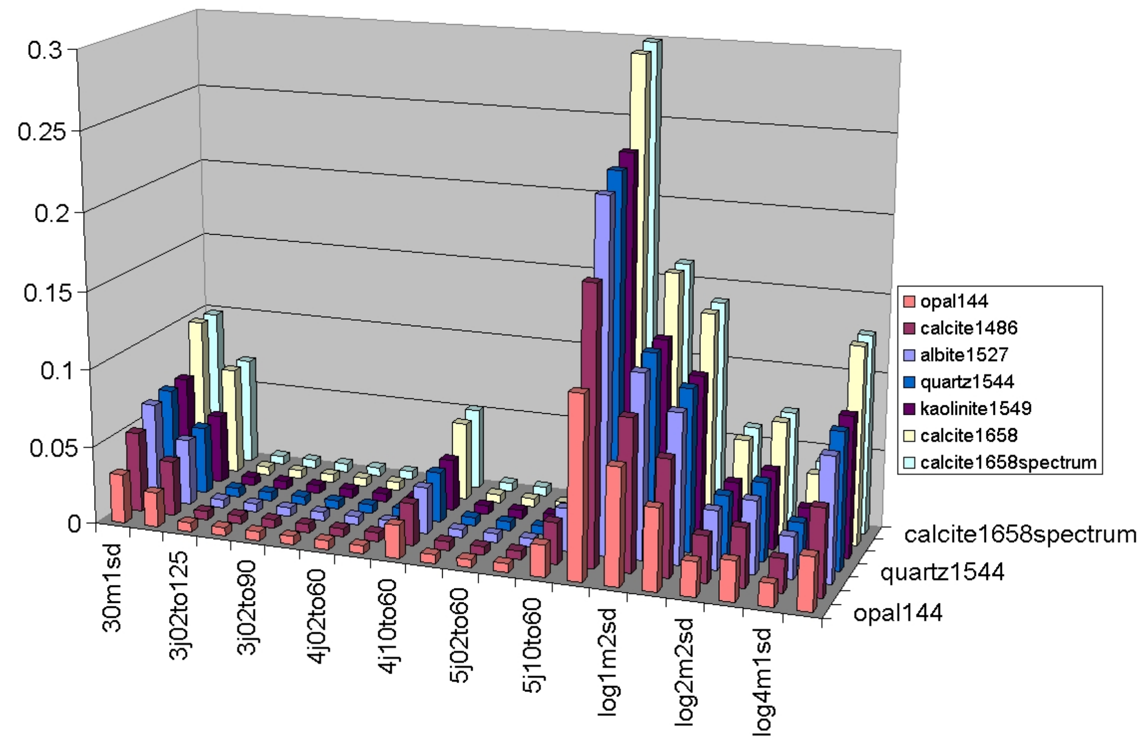


Figure 3.1.3-3: Surface reflectance at 550nm for various minerals and particle size distributions.

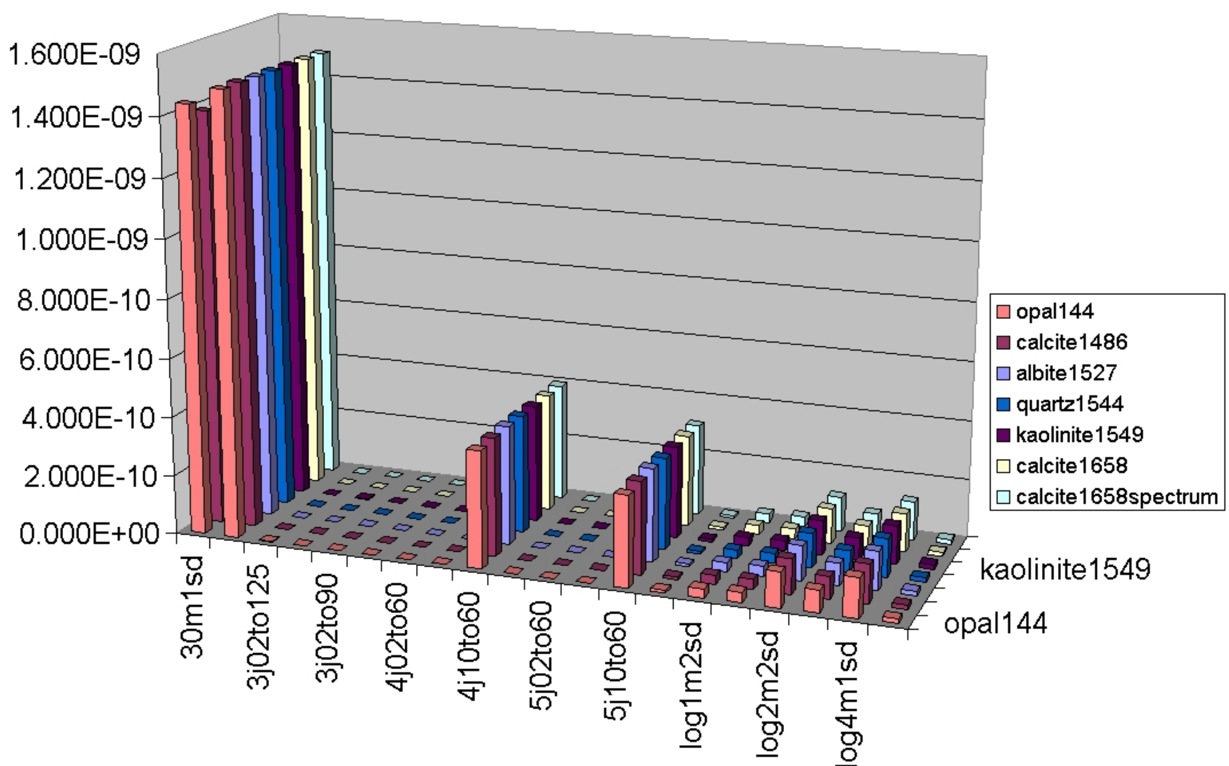


Figure 3.1.3-4: Scattering cross-sections at 550nm for various minerals and particle size distributions.

In summary, this work allowed other aspects of this MURI to move forward with the caveat that we are relying on an evolving understanding of crucial elements. It also provided insight into factors of scattering phase functions that have been downplayed because of their insignificance in Case I waters.

3.1.4 Case II Atmospheric Compensation: Simultaneous Aerosol and Water Constituent Retrieval

Research Team: Donald Taylor (Masters' student), Jason Hamel (Masters' student), Rolando Raqueño

Task Scope: In many algorithms designed to retrieve water constituent concentrations, an assumption of negligible water-leaving radiance is made in the NIR. This allows fairly accurate atmospheric correction to be applied to the oceanic imagery. Given this assumption, it is possible to derive model estimates of aerosol type and density and compensate for its effects in other regions of the spectrum. Unfortunately this assumption is only valid in areas of very low total suspended sediment (TSS) concentrations. This increased TSS load causes larger back-scattering within the water, increasing the reflectance in the NIR region, which confounds the correction algorithm and incorrectly attributes all the effects entirely to aerosols. A solution to this problem is to model the atmosphere using a proven radiative transfer system such as MODTRAN and the water reflectance due to the increased TSS using HYDROLIGHT, combine them for a given sensor altitude, and match the resulting spectra with that from an actual image taken at that altitude. This is done in the NIR (700-950nm) where we can constrain the algorithm by assuming that the contribution to reflectance of other water constituents is zero. Look-up tables (LUTs) of radiance values from modeled atmospheres and reflectance values from modeled water allow us to make this an iterative process which can be optimized to give us the best match for the pixels in question. The products of this algorithm are the TSS concentration and the atmosphere (including aerosols). The atmospheric parameters and sediment concentration can then be used to constrain the algorithm in the visible region (400-700nm) for use in extracting further constituent information.

3.2 ARO MURI – Concealed Target Simulation

Research Team: David Pogorzala, Marek Jakubowski, David Messinger

Task Scope: This project is a collaboration with University of Maryland, University of Florida, University of Hawaii, and Clark Atlanta University, and is lead by the Georgia Institute of Technology. The goal of the project is to study the phenomenology and exploitation of spectral signatures of land targets. RIT's role in the program is to provide high-fidelity synthetic scene data to the algorithm development team for testing purposes. Previous work under this project involved construction of a thermal infrared hyperspectral scene consisting of a desert area containing land mines. In the final phase of this program, RIT is providing a synthetic scene of a forested area containing targets under various levels of concealment.

Task Status: The forested scene created by RIT is named MicroScene 2. It is an area near Rochester, NY and is located within the boundaries of the larger MegaScene 1. MicroScene 2 consists of several species of trees and shrubs arranged in a semi-forested manner. The area also includes a dirt and gravel road and a large grassy field. The geometric models for the vegetation were constructed using extensive measurements of tree and branch height, width and orientation. These models were then placed in the scene according to their real-world GPS coordinates. The material attribution of the scene was done using optical properties measured by RIT.

Recent work has focused on improving two aspects of the scene. The first was to imbed MicroScene 2 into MegaScene 1. This increases both the area and complexity of the scene and allows it to be imaged from a higher altitude. The tradeoff in doing this is that the runtime of the images grows dramatically. The second area in which the scene was improved was that a wider variety of targets and confusers (non-target man-made objects) were placed in the scene. This was accomplished by inserting two types of tanks, a military truck, several automobiles and a shed into the scene. An RGB rendering of this scene is shown in Figure 3.2-1. The creation and validation of MicroScene 2 has been presented at the SPIE Optics and Photonics conference in San Diego, CA.

Figure 3.2-1: Nadir RGB rendering of the MicroScene 2 area.

3.3 NURI Algorithm Development and Implementation (Joint DIRS-LIAS project)

Sponsor(s): National Geospatial Intelligence Agency (NGA) University Research Initiative

Research Team: David Messinger, Rolando Raqueño, Emmett Ientilucci, Harvey Rhody, Bill Hoagland

Project Scope: This multi-year project developed and implemented physics-based algorithms for the exploitation of hyperspectral imagery. Three tools were developed: sub-pixel target detection, concealed or contaminated target detection, and detection of gaseous effluents. All three tools were to be developed in the IDL / ENVI analysis software for ease of transition to NGA. The project was a joint collaboration between DIRS and LIAS at RIT, as well as corporate partners with ITT Visual Information Solutions (formerly RSI) and Boeing.

Project Status: The project was completed in the winter of 2006 with a final delivery of all code, documentation, and test cases. During the final year of the program improvements were made to both the gas detection tool as well as to the implementation for handling of large Look Up Tables required for the target detection tools. The gas detection tool was finalized and tested against AHI LWIR hyperspectral imagery of a chemical facility. A typical result from this processing is shown in Figure 3.3-1.

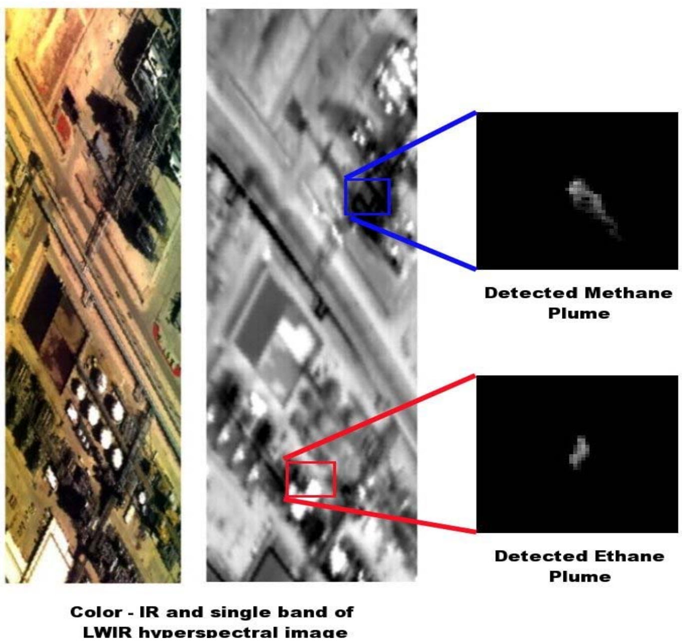


Figure 3.3-1: Detection results from the NURI gas detection tool showing detection of two plumes in the facility.

Additionally, much improvement was made in the handling of large Look Up Tables required in the physics-based algorithms. These methods rely on the data resulting from a large number of physics based model runs to characterize atmospheric effects in the target signatures. The previous methods used a simple textual tabulation of the data – a method that was unwieldy and did not allow for simple visualizations of the data. The new implementation uses the ENVI Spectral Library Format to store the data as a binary file, with user-defined identification tags. Additionally, the visualization tools available within the ENVI software can now be used to visually inspect and present the results of the look up table generation process.

All software developed under this effort has been delivered to NGA and is currently undergoing testing and evaluation by the government.

3.4 NURI Automated Scene Modeling From Multi-Sensor Modality Inputs (Joint DIRS-LIAS project)

Sponsor: National Geospatial-Intelligence Agency (NGA)

Project Scope: This NGA University Research Initiative (NURI) project is focused on reducing the time required to generate DIRSIG scenes by automating key aspects of the process. In particular, algorithms are being developed to extract the necessary geometry and material characteristics of a scene from multiple modality remote sensing data including 3D LIDAR, stereo, video, and hyperspectral imagery. Three faculty/graduate student teams are conducting research on various aspects of this project as summarized here.

3.4.1 Multi-modality Image Registration

Sponsor: National Geospatial Intelligence Agency (NGA)

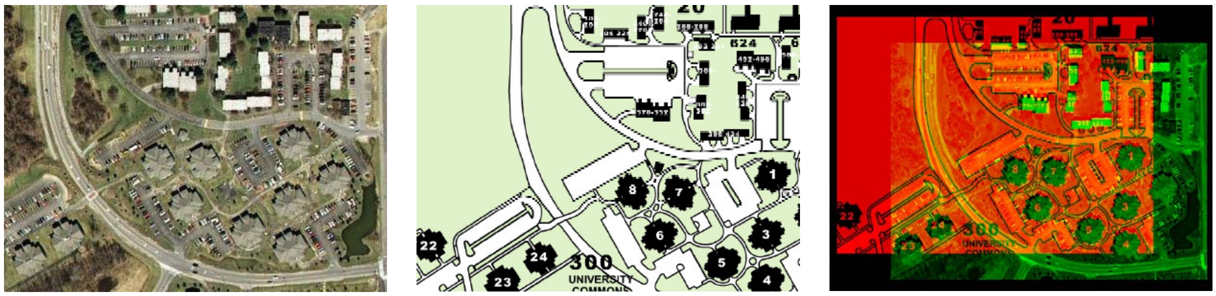
Research Team: Xiaofeng Fan (Ph.D. student) and Harvey Rhody

Project Scope: This project is a part of a NURI contract for Automated Imagery Analysis and Scene Modeling. The goal of the project is to develop tools to extract models of buildings, roads and other objects from remote sensing data to serve as input to DIRSIG. The purpose is to reduce the time required to build models of new scenes from months or years to days or weeks. The image registration task is directed at the difficult problem of registering imagery from visible and infrared cameras for the fusion of feature extraction techniques. Traditional feature correspondence techniques are problematic for this application because of the changes in appearance of objects in images from different modalities.

Project Status: Algorithms based on the maximization of mutual information (MMI) have been developed and tested on both synthetic and real IR and visible imagery. The algorithms perform well when a global transformation between image planes is applicable. A technique that we call feature-enhanced MMI has proven to be both faster and more accurate than traditional MMI, and is able to register imagery that traditional MMI fails to register. The use of multi-scale imagery via wavelet coding has been used to enable a further significant speedup of the process.

Figure 3.4.1-1: Mosaic of WASP SWIR images automatically constructed with FE-MMI

An interesting additional use of FE-MMI is registration of imagery and maps. It has been found that visible and IR imagery can be registered to maps that have a reasonable match to reality. Registration of an airborne image to an RIT campus map is shown below.



Airborne Image | Campus Map | Registered Image and Map

Figure 3.4.1-2: Registration of an airborne image to an RIT campus map is shown below.

3.4.2 Stereo Mosaic Extraction from Airborne Video Imagery

Sponsor: National Geospatial Intelligence Agency (NGA)

Research Team: Prudhvi Gurram (Ph.D. student) and Eli Saber

Project Scope: This project is a part of a NURI contract for Automated Imagery Analysis and Scene Modeling. The primary goal of this research is to automate the extraction of three dimensional structure of a scene from airborne video captured using the RIT WASP Lite sensor. Existing algorithms are time-consuming because they require huge interaction between a human analyst and image data. This research is aimed at automating this task using stereo geometry on aerial video. Once the elevation map is obtained from the stereo images, objects are identified and extracted from them. These objects are going to be expressed in a format such that it can be given as an input to DIRSIG.

Project Status: To extract 3D structure of a large urban scene, a video camera (WASP Lite) is attached to an aircraft and flown over the scene. The two requirements of covering a large area and extracting 3D geometry are satisfied by stitching the video frames into two mosaics which form a stereo pair using ray interpolation techniques. In addition to the left and right stereo pair, a mosaic along the nadir view is also built to distinguish between the apparent visible and occluded surfaces. This distinction helps us in fitting vertical planes to the occluded surfaces (in nadir view) and developing a complete CAD model of each object (especially buildings in an urban scene). Buildings and trees are two important classes of objects observed in urban scenes. So, the nadir mosaic is segmented and building/tree regions (segments) are identified and separated from terrain. The edges and corners of different surfaces of a building are identified. We match the control points along these edges to their corresponding points in left and right mosaic. Using the disparity between the corresponding points in the mosaics, an elevation map is developed at these points. Optimal surfaces are fit to each of the segments through the edge points. A prismatic building structure is assumed and constraints are applied on the neighboring surfaces with common edges. A complete CAD model of each building is provided in “obj” format. The stereo mosaic of an area over RIT’s Center for Imaging Science and the CAD model of the building extracted from it are seen in Figure 3.4.2-1.

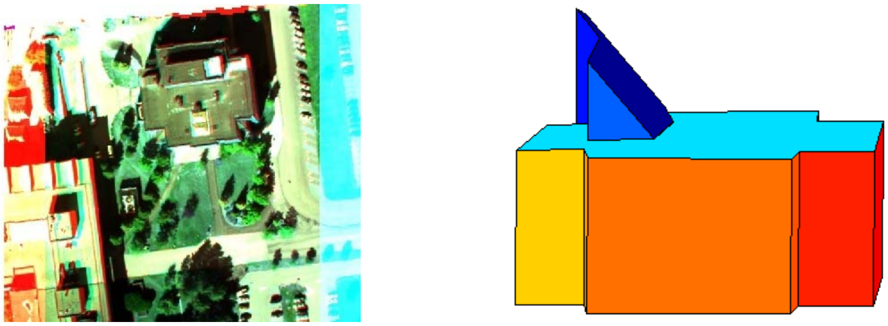


Figure 3.4.2 -1: A stereo mosaic over the RIT CIS building and a derived CAD model of the CIS building.

3.4.3 Semi-Automated DIRSIG Scene Modeling from 3D LIDAR and Passive Imaging Sources

Research Team: Steve Lach (Ph.D. student) and John Kerekes

Project Scope: This part of the Automated Scene Modeling NURI is addressing 3D CAD model extraction from LIDAR data, spatial detail extraction from high resolution data, and spectral information from spectral imagery. It also integrates the results from these efforts into the full set of input files necessary to describe a DIRSIG scene.

Project Status: An area on the RIT campus is being used as a test site to develop the necessary algorithms and to test the process. A LIDAR data collection of the campus occurred in October 2006 by Leica Geosystems, our partner in the project. Imagery obtained from Pictometry and by RIT’s WASP system has provided the high resolution spatial information.

As an example of the type of data, corresponding 2D images for a building on RIT’s campus are given in Figure 3.4.3-1. The roof’s left edge are detected in the top image via a Canny edge detector, while the corresponding points are highlighted in the LIDAR image and the appropriate edge has been flagged in the CAD projection, demonstrating the achieved object registration among the data types.

Figure 3.4.3-1: Frame-Array Image (top), 2D projection of LIDAR data (left) and CAD model (right).

The LIDAR data are used not only to extract the building geometry and CAD model, but also to derive the surface elevation map, and in some cases, to detect and scale trees for placement in the scene.

A surface cover type classification is derived from available spectral imagery. Figure 3.4.3-2 shows such a classification result for the area of interest on the RIT campus. Using this map and spectra from a reflectance library matching the various materials, the surfaces are attributed with appropriate spectra. Figure 3.4.3-3 shows a final DIRSIG scene rendering using inputs derived from the various remotely sensed images and corresponding libraries.

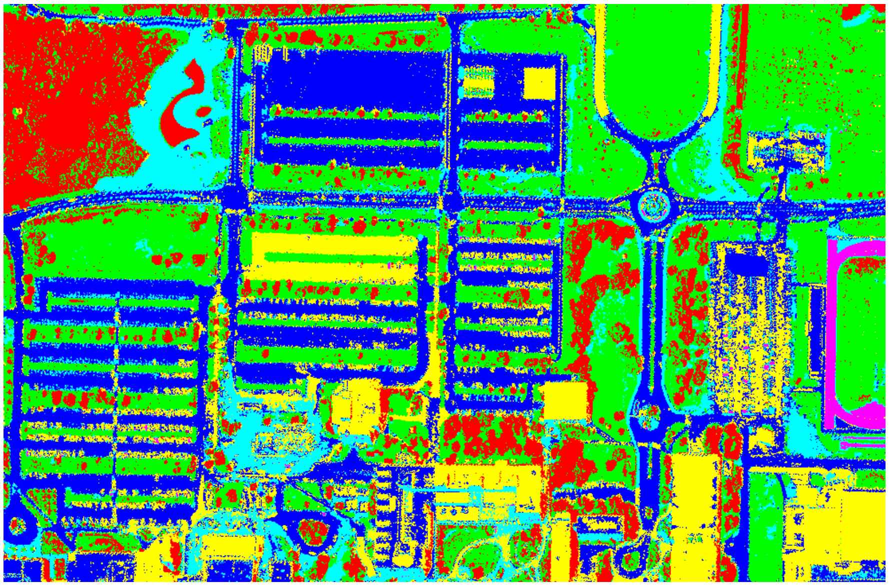


Figure 3.4.3-2: Classification map of portion of the RIT campus derived from a WASP spectral image.

Figure 3.4.3-2: DIRSIG rendering of RIT campus derived from remotely sensed imagery and library databases.

3.5 Integrated Sensor System Initiative (ISSI)

Sponsor: NASA

Project Scope: Rochester Institute of Technology (RIT) has initiated a facility for the rapid prototyping of a new generation of remote sensing architectures, sensors, and data fusion capabilities. This program is called the Integrated Sensing Systems Initiative (ISSI) and is focused on the fusion of overhead sensor data with application specific ground sensors into an integrated information product that will provide users with a more complete view of an event providing greatly enhanced situational awareness.

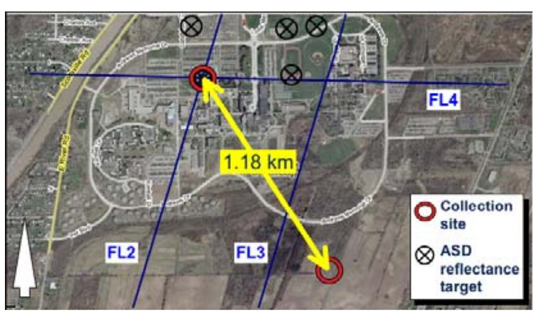
3.5.1 Atmospheric Compensation and Reflectance Retrieval

Research Team: Brent Bartlett (Ph.D. student) and John Schott

Project Scope: This project is aimed at development of improved methods for atmospheric compensation in the presence of clouds. Specifically, it is designed to develop and demonstrate methods that could be used for operational remote monitoring recognizing that clouds will be present in the surround for a large fraction of the available imagery. As part of the ISSI project, we focused on potential measurement devices that might be deployed in the study region to improve the potential for atmospheric compensation.

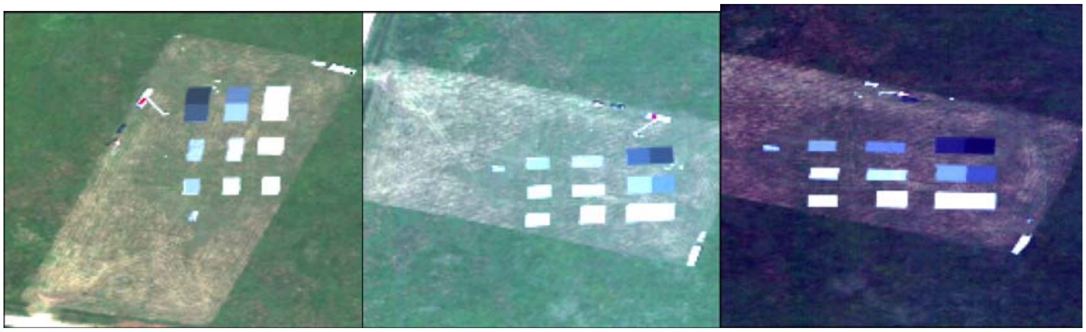
Project Status: The project is nearing completion (expected October 2007). A method that utilizes a modified empirical line method (ELM) has been developed and demonstrated to improve atmospheric inversion to reflectance in the presence of clouds in the surround.

The method involves use of a simple solar irradiance meter with sun-shade at the primary site where the ELM panels are deployed. It then uses either a second solar irradiance meter at a second site (see Figure 3.5.1-1) or a fisheye lens (see Figure 3.5.1-2) to adjust the ELM solution to account for illumination variations due to clouds in the surround. A set of test images (see Figure 3.5.1-3) from the DOE atmospheric radiation measurement (ARM) site in Lamont, Oklahoma have been identified to test the performance of the direct measurement and fisheye image/modeling approach. Initial results indicate that significant improvement should be achieved by this approach and that methods for better operational use may be available through use of satellite images to map cloud patterns in place of the fisheye lens images.



3.5.1-1: The physical layout of the Multi Modal Collect (MMC) over RIT campus showing the primary site and the secondary site to the southeast.

3.5.1-2: Fisheye lens images of the cloud conditions during flight lines one, nine, and fifteen which occurred at 11:10, 11:44, and 12:10 respectively.



(a) run07 (b) run10 (c) run15

3.5.1-3: **Calibration site from each flight-line. Atmospheric effects have not yet been accounted for.**

3.5.2 WASP Situational Awareness Demonstrations

Sponsor(s): NASA

Research Team: Harvey Rhody, Don McKeown, Jason Faulring, Bob Krzaczek, Bill Hoagland

Project Scope: This project is funded under the Integrated Sensing Systems Initiative (ISSI), a multi year program begun in 2004 to investigate the utility of applying realtime imaging and non-imaging sensor data to the problems associated with wildfire management and other disaster response. RIT has developed a high performance incident mapping system consisting of a modular architecture capable of

- Producing ready to view image maps onboard the aircraft in realtime
- Easy operation by a single operator with minimal training
- High resolution maps day or night (color and thermal infrared capable)
- Viewable in Google Earth or other standard viewer software

- Interface with digital radio link for realtime transmission of imagery from the aircraft

Project Status: In 2007, the RIT sensor system was deployed on several demonstration missions for local county, state, major utility company organizations. These demonstrations showed the ability to capture airborne imagery, geo-reference the imagery, and produce integrated GIS products in near realtime. For example the RIT sensor was flown in support of a disaster drill for the Ginna nuclear power station. Figure 3.5.2-1 shows an example color image produced in realtime and overlayed on a USGS DRG map.

Figure 3.5.2-1: Realtime image of nuclear power plant overlaid on USGS map

Figure 3.5.2-2 shows an example of a simulated flood mapping mission in which the RIT sensor mapped over 40 miles of a river and produced a complete GIS product in less than 2 hours from the time of aircraft launch. The overlay mosaic is imagery captured in the shortwave infrared which is very well suited for delineating water. The inset is from the color infrared camera which operates simultaneously with the infrared cameras to produce highly detailed imagery.

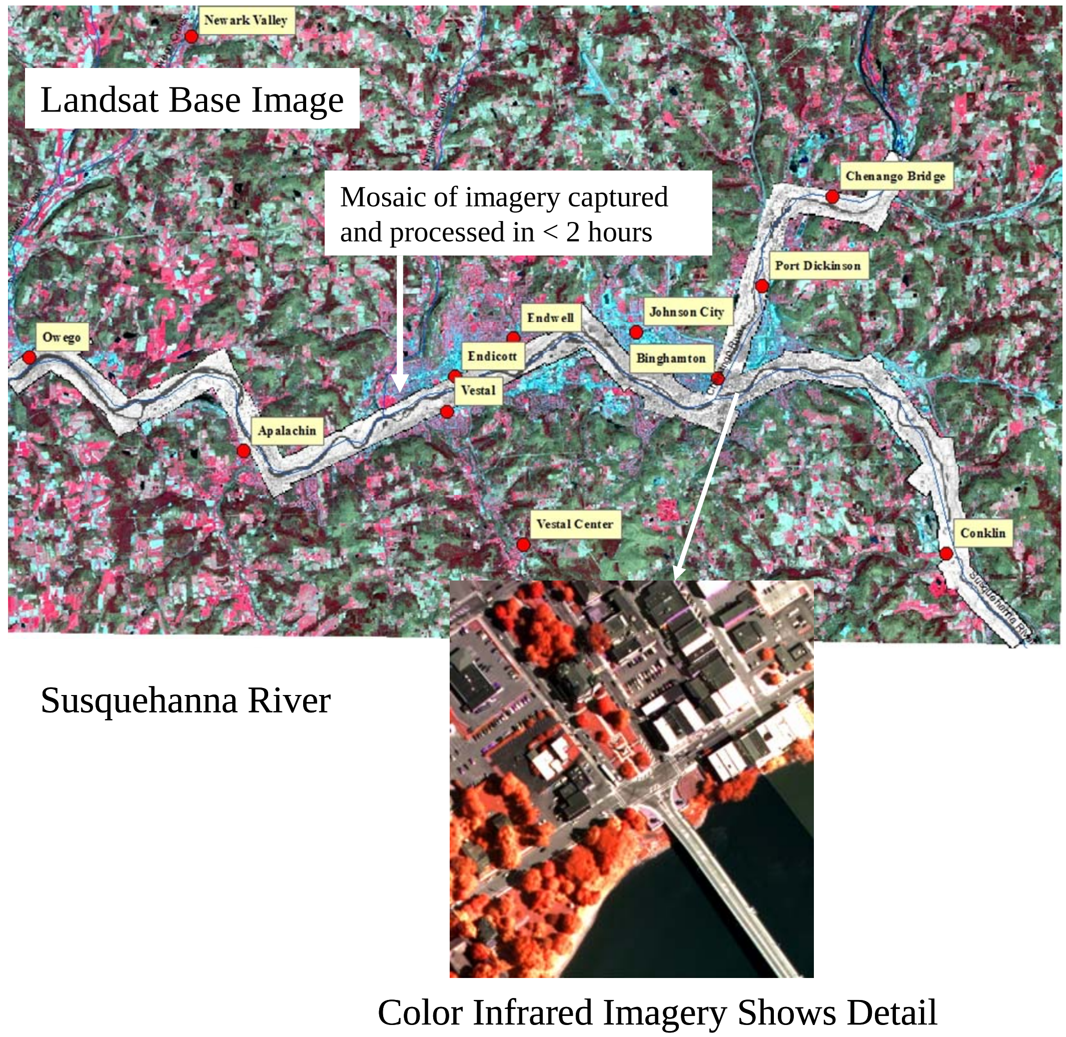


Figure 3.5.2-2: 40 miles of river mapped and rendered in GIS in less than 2 hours

3.5.3 Monitoring Algal Blooms using Airborne Multispectral Data

Sponsor(s): NASA,

Research Team: Shari McNamara (Masters' student) and Anthony Vodacek

Project Scope: This project was a collaboration with SUNY- Environmental Science and Forestry. The goal of the project is to develop algorithms for detecting cyanobacteria (blue-green algae) based upon the unique spectral signature of the cyanobacteria pigments. Previous studies of cyanobacteria assessed the detection of these potentially harmful algae using the band sets available on existing satellite systems. Our goal is to find an optimal band set that can be used with our flexible, small, and inexpensive multispectral sensor, WASP-Lite.

Project Status: WASP-Lite was flown over Lake Champlain in fall 2006 during a time of abundant cyanobacteria (blue-green algae) growth in the lake. The band pass filters used on WASP-Lite were 405, 550, 632, 650, and 870 nm. These filters were chosen to respond to reflection or absorption bands due to the algal pigments chlorophyll and phycocyanin.

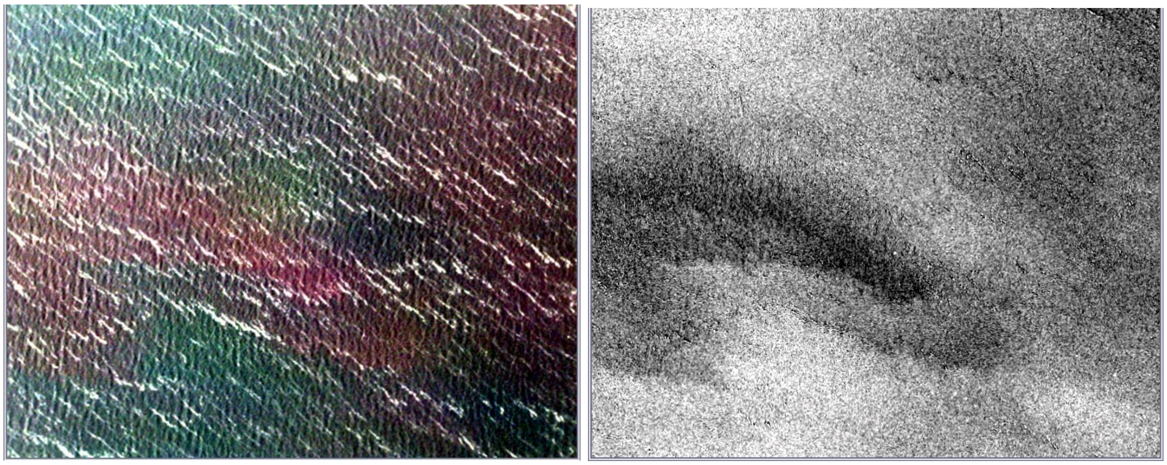


Figure 3.5.3-1: (left) Three band false color WASP-Lite image, where the 550, 630, and 650 nm bands are assigned to RGB, respectively. The diagonal white streaks are foam lines on the water surface and the red patches correspond to high concentrations of algae in the water. (right) Principal component analysis of the same multispectral image to remove the effects of the foam and sunglint off the water surface and enhance the algal pigments in the water. Dark areas are high concentrations of algae.

The first finding of the project was that stringent band to band registration is critical to the success of this approach since the images contain features such as foam lines and sun glint off the wave facets which have very strong signals. Secondly, the ability to resolve patterns of algae distribution in the water at very fine scale makes it very difficult to match water sample locations with image data (Figure 3.5.3-1). Future work in establishing these techniques for monitoring algae requires better spatial sampling such as can be accomplished with flow through instrumentation (such as fluorometers) that can determine algae concentrations as a boat is underway.

More details on this project can be found in Shari McNamara's M.S. thesis titled "Using Multispectral Sensor WASP-Lite to analyze harmful algal blooms."

3.6 Landsat TM and Landsat ETM+ Thermal Calibration

Sponsor(s): NASA Goddard

Research Team: Frank Padula (Masters' student), John Schott, Nina Raqueño, Tim Gallagher

Project Scope:
DIRS has a long history of supporting the thermal calibration of NASA's suite of Landsat satellites. The research focus for this period included continued monitoring of the Landsat ETM+ thermal band and further refinement of the Landsat TM calibration history. During this year much effort has been dedicated to collecting ground truth for both Landsat instruments and updating RIT's Landsat 5 TM calibration procedure. It has also included development of a proposed method to more effectively correct buoy data to surface temperatures that could significantly improve the historical calibration data for Landsat 5.

The sensor performance is compared to ground truth temperatures collected from Lake Ontario and Lake Erie. Surface measurements are augmented with simultaneous thermal imagery with RIT's MISI airborne sensor (cf. Figure 3.6-1). The specific atmospheric conditions are taken into account by implementing an interpolated atmospheric profile within MODTRAN. Final calibration results are reported as a comparison of sensor reaching radiances and known surface radiances propagated to the sensor altitude (cf. Figure 3.6-2).

Project Status:
Landsat calibration has been a multi-year monitoring project since 1995. Results and recommendations were presented to the Landsat Science Team in December 2006 and June 2007. DIRS results were comparable to an independent team's results. At this time, Landsat ETM+ remains stable and no changes to the calibration coefficients are necessary. Both teams show a slight bias (0.092 $W/m^2 sr \mu m$) in Landsat TM and a change to calibration processing was implemented in April 2007. Given that Landsat TM was not monitored continuously since its launch in 1984, DIRS is now using historical NOAA buoy temperature data to fill in the temporal gaps.

This continued monitoring and calibration of the Landsat TM and ETM+ sensors is essential to long-term global change studies.

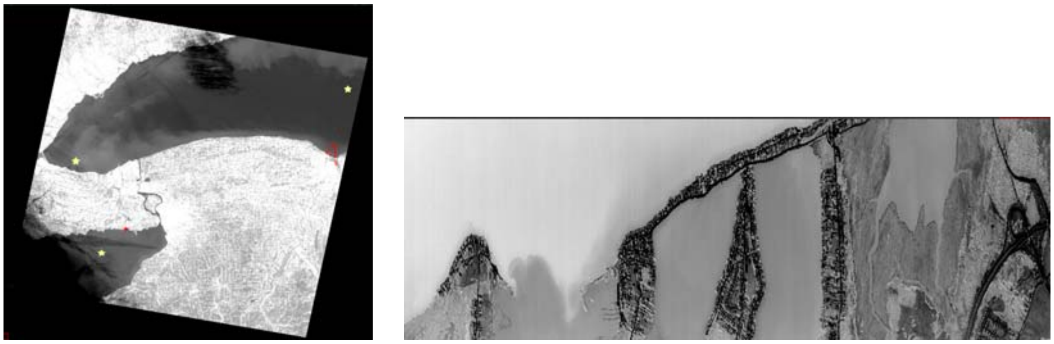


Figure 3.6-1: Example of Landsat 5 thermal imagery (left) of Lake Ontario and Lake Erie with ground collection sites indicated with red '+' and buoy locations indicated with yellow stars. On the right is an example of higher resolution thermal MISI imagery of the Rochester Lake Ontario shoreline.

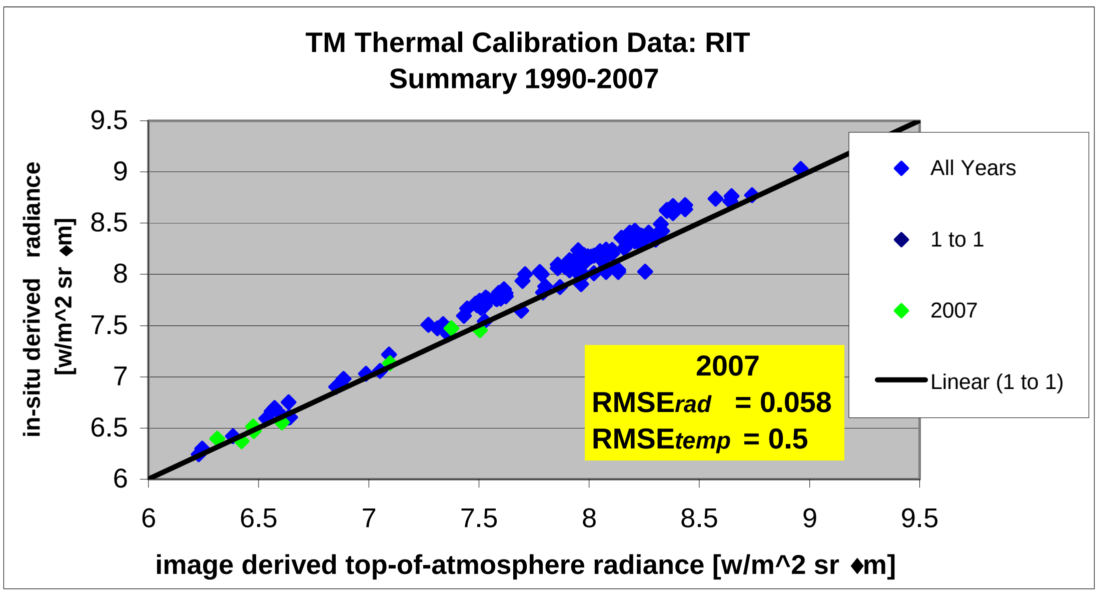


Figure 3.6-2: A comparison of previous Landsat TM calibration analysis to early spring 2007 results (Note the 2007 data include the correction recommended by the Calibration Team). Results are reported as a comparison of sensor predicted radiances to ground based observations.

3.7 IC Postdoctoral Research Fellowship Program – Stochastic Target Space Modeling

Sponsor(s): Intelligence Community/NGA

Research Team: Emmett Ientilucci and John Schott

Project Scope:
Traditional approaches to hyperspectral target detection involve the application of detection algorithms to atmospherically compensated imagery. Rather than compensate the imagery, a more recent approach uses physical models to generate target sub-spaces. These *radiance* sub-spaces can then be used in an appropriate detection scheme to identify potential targets. The generation of these sub-spaces involves some *a priori* knowledge of data acquisition parameters, scene and atmospheric conditions, and possible calibration errors. Variation is allowed in the model since some parameters are difficult to know accurately. Each vector in the subspace is the result of a MODTRAN simulation coupled with a physical model. Generation of large target spaces can be computationally burdensome. This research explores the use of statistical methods to describe such target spaces. The statistically modeled spaces can then be used to generate arbitrary radiance vectors to form a sub-space.

Project Status:
To date, two models have been developed, one an improvement on the other. Both are variation on a 3rd order, 3 variable polynomial of the form

$$
\begin{aligned}
f(x,y,z) = &\\
&\left(\beta_1 x^3 + \beta_2 y^3 + \beta_3 z^3\right) + \left(\beta_4 x^2 + \beta_5 y^2 + \beta_6 z^2\right) + \left(\beta_7 x + \beta_8 y + \beta_9 z\right)\\
&+\left(\beta_{10} x^2 y^2 z + \beta_{11} y^2 z^2 x + \beta_{12} z^2 x^2 y\right) + \left(\beta_{13} x^2 yz + \beta_{14} y^2 xz + \beta_{15} z^2 xy\right)\\
&+\left(\beta_{16} xy + \beta_{17} xz + \beta_{18} yz\right) + \beta_{19} xyz + \beta_0
\end{aligned}
$$

Figure 3.7-1 shows results for the older model while Figure 3.7-2 showns improved (lower residuals) results for the same target space.

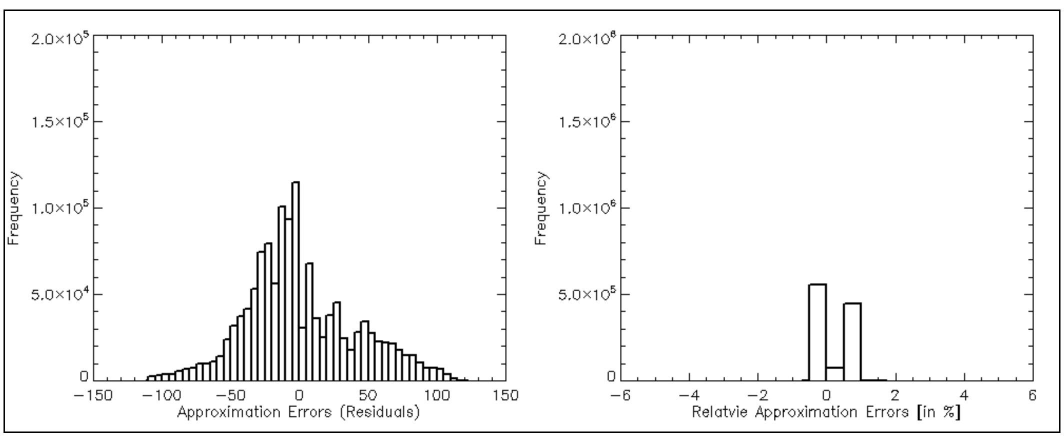


Figure 3.7-1: Residuals (left) and relative errors (right) obtained using the (older) full 5 variable, 3rd order, model. The maximum and minimum residuals are 116.8 and -113.8, respectively. This was for a target space consisting of 8575 vectors.

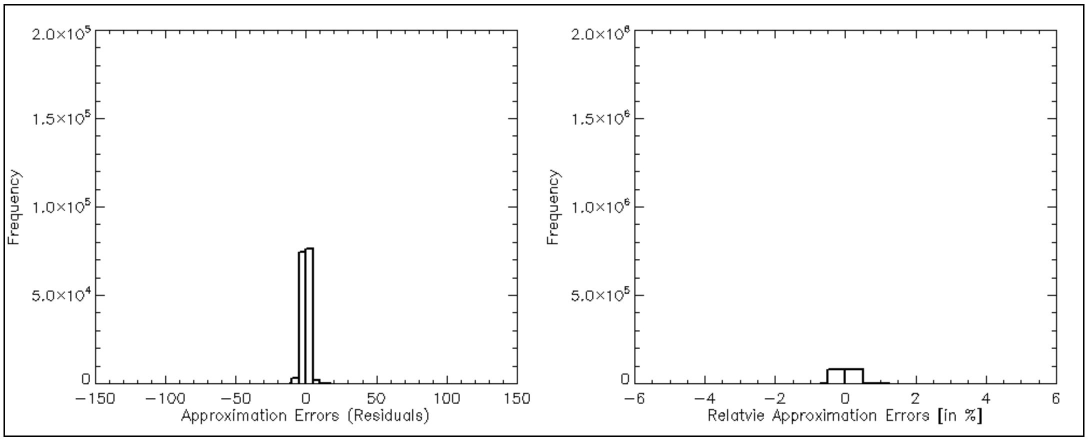


Figure 3.7-2: Residuals (left) and relative errors (right) obtained from (newer) piecewise model. Once again, this is a 3rd order model. The maximum and minimum residuals are 13.7 and -15.0, respectively. This is an aggregate histogram obtained from piecewise residual results. This was for a target space consisting of 8575 vectors.

3.8 IC Postdoctoral Research Fellowship Program – Effects of Humidity on Atmospheric Transmission for Infrared Sensors

Sponsor(s): Intelligence Community Postdoctoral Fellowship (NGA)

Research Team: Rolando Raqueño, Carl Salvaggio, Robert Kremens

Project Scope: The project is investigating the phenomenon of anomalous transmission effects in the LWIR. This atmospheric anomaly is characterized by low transmissions in the LWIR while having relatively high transmissions in the visible region. The approach is to use radiative transfer modeling to try to determine if and when anomalous transmission conditions arise due to small water aerosol particles and/or hygroscopic aerosol particles under certain humidity conditions. The modeling will require precise control of the spectral optical properties of the particulates (as calculated using Mie theory) along with their position in the atmospheric column. Overhead imagery is under study to verify this phenomenon and establish its linkages to humidity conditions. Small ground-based collections will also be performed in an attempt to observe this phenomenon and its relation to atmospheric conditions.

Project Status: Preliminary modeling using MODTRAN4 and the included Mie scattering code has highlighted deficiencies in the current interface implementation between the two codes. A newer version has been requested which will simplify the analysis by allowing to define a single aerosol layer with the appropriate spectral optical properties in order to isolate the impact of the very small water aerosol particles under consideration. Preliminary ground-based collection of LWIR and visible imagery have been conducted using the WASP-lite sensor, but the need for persistent surveillance to image a rare event has initiated the integration of a sensor package better suited for long-term imaging and environmental monitoring. Plans are underway to merge instrumentation resources and additional collection experiments with the Cooling Tower Project.

Figure 3.2-1: Video sequence of diurnal collection over water (Conesus Lake) (left) Visible frame from sequence (right) Corresponding LWIR Thermal Image.

3.9 Revolutionary Automatic Target Recognition and Sensor Research (RASER) Project: Vehicle Tracking in an Urban Environment with Multitemporal Airborne Hyperspectral Imaging

Sponsor: Air Force Research Laboratory (AFRL) Sensor Directorate ATR & Fusion Algorithms Branch (SNAT)

Research Team: Jason Casey (Masters' student) and John Kerekes

Project Scope: This project is exploring the technical issues, phenomenology and capability of airborne hyperspectral imaging systems to detect and track civilian vehicles in a cluttered urban environment.

Project Status: In July 2006, the project conducted a successful repeat pass airborne hyperspectral imagery collection coincident with the movement of ground truthed volunteer vehicles on the ground. The Cooke Hyperspectral Airborne Repeat Measurement (CHARM) experiment is proving to be an excellent data set from which to study this problem. Five vehicles were pre-positioned and then moved between passes (seven occurring within 90 minutes) of the HyVista HyMap airborne hyperspectral imager in the town of Cooke City, Montana. This location was chosen since it is the field site of our partner in the project, HyPerspectives, a small business located in Montana and to leverage the availability of the HyMap sensor which was in the area for several other collection experiments. Figure 3.9-1 presents a sample of the HyMap imagery showing the Cooke City area and its surrounds.

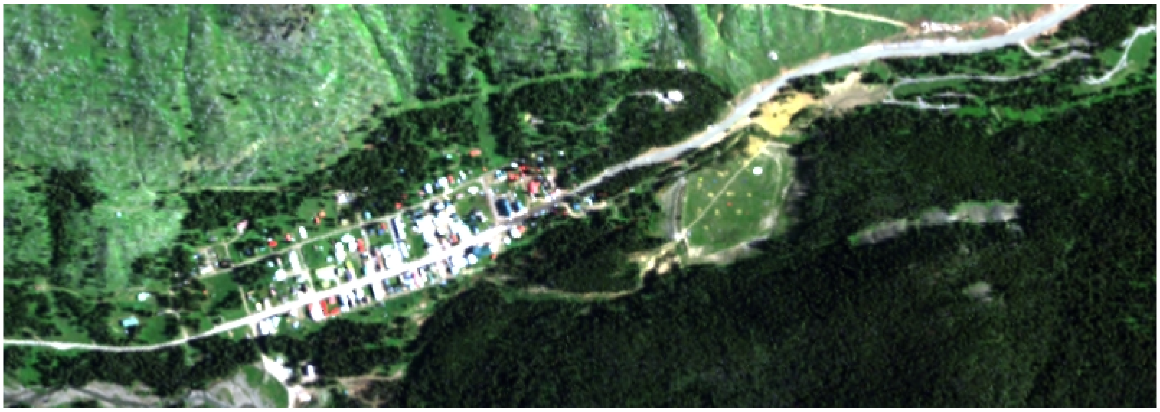


Figure 3.9-1: Color rendition of HyMap HSI image of Cooke City, MT during CHARM 2006.

The CHARM data continue to be analyzed but early results indicate it is possible in some cases to use the spectrum of a vehicle of interest collected in one pass to find the vehicle after it moved to a nearby location in a subsequent pass of the sensor. However, this is very dependent upon the vehicle having a spectrum (color) that is unique to avoid false alarms. This project also has available high resolution LIDAR data of the same area (collected in 2003) which has been shown to help mitigate false detections in the tracking by eliminating fixed structures from consideration when searching the image for the vehicles of interest.

Another focus of the efforts this year has been on the study and characterization of errors introduced by spectral misregistration between groups of spectral channels in imaging spectrometers. RIT's line scanning Modular Imaging Spectrometer Instrument (MISI) uses two separate apertures to feed spectrometers covering the visible and near infrared (NIR) portions of the spectrum. Since these apertures sense radiance from slightly different locations on the ground during data collection, there is an inherent misregistration between the resulting images. The sensitivity and impact of this artifact is being studied through the use of the DIRSIG image simulation tool. Figure 3.9-2 shows a portion of the MegaScene I area with 140 vehicles placed across the scene. By creating the image at high resolution and then rendering it at 10x greater pixel size, we have been able to create images that are misregistered at 0.1 pixel increments.

Figure 3.9-2: Color rendition of MegaScene I area with 140 vehicles placed in scene.

Various algorithms are being applied to the simulated images with a range of misregistrations. Figure 3.9-3 shows an example resulting ROC curve (probability of detection vs. probability of false alarm) for a particular algorithm and vehicle color. This result shows the degradation resulting from having a misregistration between the visible and near infrared parts of the spectrum as well as the degradation of performance when using bands only from the visible or NIR.

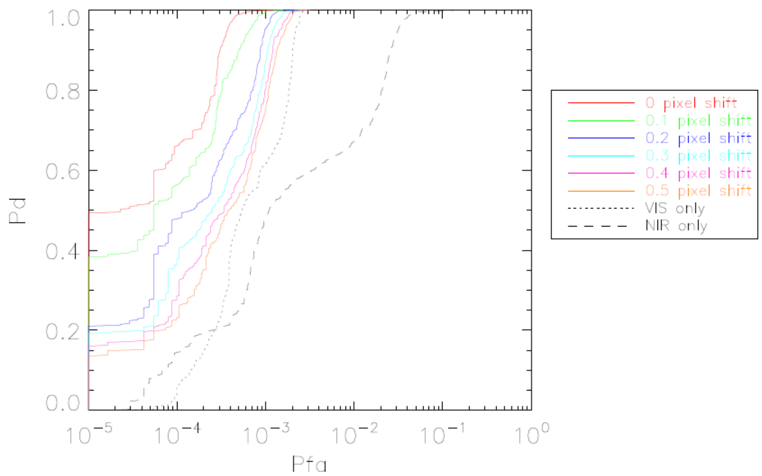


Figure 3.9-3: Target detection performance with misregistered data or using a portion of the spectrum.

3.10 Apparent Temperature of Cavity Objects from Thermal Imagery

<u>Sponsor</u>: Savannah River National Laboratory

Research Team: Matthew Montanaro (Ph.D. student), Carl Salvaggio, David Messinger, Scott Brown

Project Scope: Determine the internal temperature of a mechanical draft cooling tower (MDCT) from remotely sensed thermal imagery for input to process models

Project Status: The problem of determining the temperature of a MDCT can be separated into two parts: the radiance leaving the tower and the radiance reaching the sensor. The radiance leaving the tower is dependent on the optical properties of the tower materials and also the internal geometry of the tower. Simulations using the DIRSIG software developed by the DIRS laboratory at RIT were used to investigate the dependence on the optical properties of the tower materials and on the number of internal reflections taking place inside the tower on the tower leaving radiance. The result of these simulations indicate that assuming the material has a relatively high emissivity and is somewhat specular in the long wave infrared, the tower radiance approaches the blackbody radiance given at least three internal reflections have occurred. In other words, the tower behaves like a blackbody if the previously mentioned assumptions hold.

The tower radiance is then propagated through the exhaust plume and through the atmosphere to arrive at the sensor. The tower exhaust consists of a warm plume with a higher water vapor concentration than the ambient atmosphere. The MODTRAN software was used to study the effect of this plume under a variety of conditions. The result of this study demonstrates that the plume will be the largest source of error when attempting to derive the temperature of the MDCT. Techniques must be developed to compensate for this error introduced by the plume. We are currently working to develop a regression relationship among all the variables that might influence the derived temperature of the MDCT.

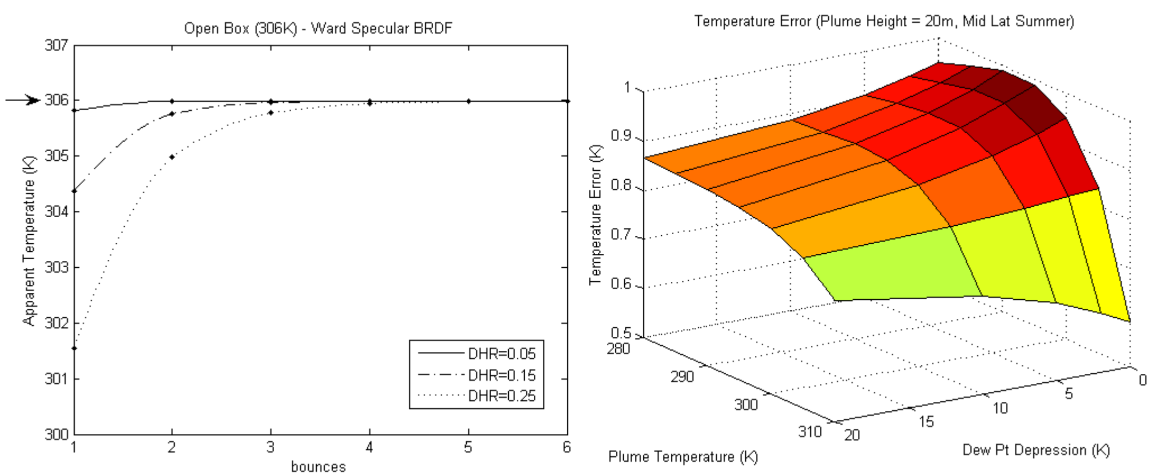


Figure 3.10-1: Results of the DIRSIG simulation (left) demonstrating that the tower behaves like a blackbody if the materials have relatively high emissivities, are somewhat specular, and there have been a sufficient number of internal reflections. The MODTRAN study (right) indicates that the temperature error introduced by the plume is dependent on the air temperature, concentration of water vapor, and the height of the plume.

3.11 Gaseous Effluent Monitoring System

<u>Sponsor(s)</u>: Environment Protection Agency (EPA) / D&P Instruments

<u>Research Team:</u> Natalie Sinisgalli (B.S. Student), Robert Kremens, David Messinger, Carl Salvaggio

<u>Project Scope</u>: This project was focused on the development of a field portable device for the detection, identification, and quantification of gaseous effluent plumes from industrial facilities for compliance monitoring (MARLIN).

3.11.1 Instrument Development

<u>Project Scope</u>: RIT's role in the instrument development task was to develop, using commercially available components, a system that would allow for the observation of the plume using both a visible and midwave infrared camera while simultaneously collecting spectral radiance data from a single targeted position within the observed plume. These separate systems were to be bore-sighted for a fixed operating distance and provide for the user to make adjustments to the instrument sighting while deployed in the field.

<u>Project Status</u>: The system has been delivered to the EPA and is currently undergoing testing at the sponsor's site. The system consisted of a standard silicon based miniature video camera mounted in the sighing telescope of a D&P Instruments Model 202 TurboFT spectrometer. This allows for recording of the exact field of view that the spectrometer is collecting. This system is boresighted with a FLIR Systems GasFindIR midwave, mechanically cooled, video camera that also collects a video stream. All the video streams are simultaneously recorded on a portable, DC powered, digital video recorder in a split screen format. This latter data can be used to help determine the flow rate for the gas as described in the next section.

(a) (b) (c)

Figure 3.11-1: (a) Front view of MARLIN systems illustrating the D&P Instruments TurboFT equipped with a 6-inch telescope collecting optic, the in-path miniature video camera, and the FLIR Systems GasFindIR, (b) Rear view of the MARLIN system indicating the presence of the split-viewing screen for in field observations, and (c) Field deployed system with digital video recording electronics shown.

3.11.2 Gaseous Effluent Monitoring System - Algorithm Development and Implementation

<u>Project Scope</u>: RIT's role under the algorithm task was the development of data processing algorithms to extract both qualitative and quantitative information from the data collected by the MARLIN sensor. The desired quantities to be estimated are (1) gas species identification and (2) the gas mass flow rate estimation. Software was implemented in the IDL / ENVI processing environment and included a Graphical User Interface for ease of use.

<u>Project Status</u>: The algorithms designed to extract the necessary information from the MARLIN sensing system were developed and implemented during the first half of the year. Final implementation and testing at RIT was completed during the winter and spring of 2007. The algorithm proceeds through several steps to achieve the desired estimates. First, the spectrometer data is used to estimate the most likely constituent gas species in the plume by comparing the measured spectrum with a library of gas spectra. Next, through user interaction with the software, the plume size and flow rates are estimated from the IR video frames. This information is combined with estimates of the signature "strength" from the spectrometer to estimate the gas concentration. Finally, this information is combined to estimate the mass flow rate of the gas (in grams / hour) exiting the leak. Figure 3.11.2-1 shows the second of four graphical user interfaces in the software. The software has been delivered back to the EPA for testing during field collections to take place during the summer of 2007.

Figure 3.11.2-1: GUI in which the user interacts with the software to determine leak flow rate and size.

3.12 Oblique HSI Algorithm Development

Sponsor: VirtualScopics Inc., Naval Research Laboratory (NRL)

Research Team: Emmett Ientilucci and David Messinger

Project Scope: With the recent development of several new long-range oblique hyperspectral sensors, it is important to understand any new limitations that may be encountered in the data (relative to that obtained at nadir) due to the longer stand-off distances and the oblique path through the atmosphere. Because the affects of the atmosphere are highly wavelength-dependent, we expect long-range sensors to be far more limited in their spectral range. Under this task RIT will conduct several studies to understand the phenomenology and driving factors associated with exploitation of oblique hyperspectral imagery. Standard radiative transfer and scene simulation tools will be used.

Project Status:

Sensor Reaching Radiance Estimates

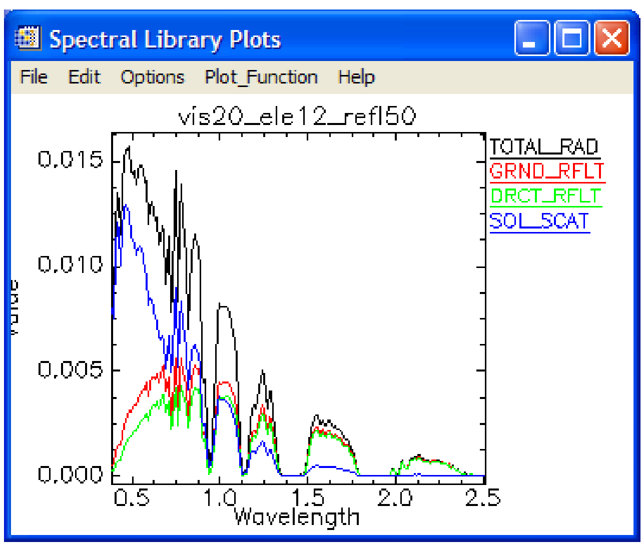


Figure 3.12-1: Plot of sensor-reaching radiance (TOTAL_RAD) as well as individual components that make up the sensor-reaching radiance (i.e., GRND_RFLT, DRCT_RFLT, and SOL_SCAT). It can be seen that at a large slant range, most of the signal reaching the sensor, in the VIS, is from atmospheric scattering and upwelled radiance and not the target.

Contrast Functions

Presented is the contrast in L_{TOTAL_RAD} for VIS=20km and azimuth angle=109.7. That is the sun is *behind* the sensor. Variation occurs in target reflectance (i.e., 50 and 5) and elevation angle (i.e., nadir and θ=12 degrees). Results of this contrast can be seen in Figure 3.12-2 where bands associated with water absorption have been removed (i.e., water regions 0.940, 1.130, 1.4 and

1.9 um). For example, around 650 nm, you get about the same level of contrast (about 20%) when you image a 5% target nadir as you do imaging a 50% target at a 12 degree elevation.

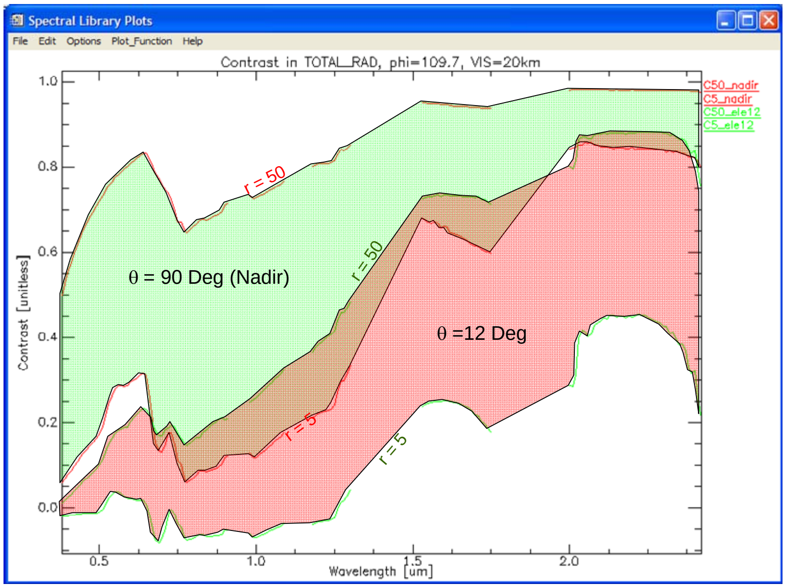


Figure 3.12-2: Shaded in regions illustrating ranges of contrast for nadir and 12 degree viewing. RED is range in contrast for NADIR viewing (target r = 50 to 5) and GRN is range in contrast for 12 degree viewing (target r = 50 to 5).

3.13 LACOSTE Modeling

Project Scope: RIT is supporting the feasibility study of a coded aperture sensor named LACOSTE. The Air Force Research Laboratory (ARFL) is performing the actual modeling of this instrument.

Project Status: RIT has provided user support, scene improvements, and enhancements to the DIRSIG modeling software.

(1) Therm Time Step Optimization

RIT's DIRSIG modeling tool has been upgraded to account for the thermal mass of materials being modeled. Temperature predictions for materials with little thermal inertia, such as leaves and metals, have been significantly sped up. Typical scenes modeled in the emissive region undergo a two-fold speed increase in total run time. In extreme cases, such as Microscene1 slant views, six-fold speed increases have been observed.

(2) Implementation and Automation of a Thermal Validation

The "Rooftop Validation", used in several published DIRS papers, has been reproduced. This establishes the validity and correctness of DIRSIG's temperature predictions and thermal images. Calculating and producing validation outputs has been automated. This means that all future versions of DIRSIG can easily be checked for correctness.

(3) New Megascene1 Trees

A new set of trees has been created for Megascene1. Unlike the original trees, these feature full geometry for branches and twigs. Besides the "standard", foliated versions, a set of defoliated trees has been produced to enable winter simulations. Furthermore, the new trees were created using an open source tool; users will no longer need to purchase a TreePro license to access high-fidelity trees.

3.14 Landsat Data Continuity Mission (LDCM)

Sponsor: US Geological Survey

Research Team: Aaron Gerace (Ph.D. student), Nina Raqueño, John Schott

Project Scope:
The goal of this research effort is to evaluate the potential for the improved features of the Landsat Data Continuity Mission (LDCM) to contribute to water quality studies. Specifically, we wish to determine if the advancements made to the Enhanced Thematic Mapper Plus (ETM+) are significant enough to enable the use of the LDCM sensor as a calibration tool to a hydrodynamic model of river discharge.

Project Status:
Preliminary studies have been designed to determine what affect a deep-blue band, 12-bit quantization, and improved signal-to-noise ratios will have on our ability to retrieve water constituents (Chlorophyll, Suspended Minerals, and Colored-Dissolved Organic Matter). In an effort to evaluate just the sensors abilities, atmospheric effects can be ignored by developing a scene through the use of Hydrolight simulated data. Hydrolight is an in-water radiative transfer code that can be used to determine the water-leaving signal of a water column. Then by developing a model of the ETM+ and LDCM sensors, a retrieval process can be implemented to determine how effective each sensor is in retrieving water constituents. Table 3.14-1 illustrates LDCM's potential to be used in the retrieval process by showing the errors incurred in retrieving the three major constituents. Clearly LDCM outperforms ETM+ and is well under the desired 20% error standard.

	Chlorophyll	Suspended Minerals	CDOM
ETM+	10.9%	20.0%	22.9%
LDCM	5.4%	5.0%	6.4%

Table 3.14-1: Constituent retrieval errors for the ETM+ and LDCM sensor. Errors expressed as percentage of the range of values we can expect to observe in a scene containing case 2 waters.

Encouraged by the preliminary results, further studies are being conducted with the LDCM sensor. Using the AVIRIS data collected by the DIRS group on May 20th, 1999, we can evaluate LDCM's efficiency in performing the retrieval process on real data. By sampling the AVIRIS scene to the spectral response of the LDCM sensor and using an appropriate atmospheric correction algorithm, the constituent retrieval process can be simulated for the Rochester embayment. Although this stage of the study is still in its infancy, promising results have been obtained. Figure 3.14-2 illustrates our ability to retrieve the three constituents from the Genesee river plume, which is the area we wish to use LDCM as a calibration tool.

Ongoing efforts include the determination of the optimal atmospheric correction algorithm and the development of a hydrodynamic model.

	Chlorophyll	Suspended Minerals	CDOM
LDCM	2.1%	10.0%	19.3%

Table 3.14-2: Constituent retrieval errors for the LDCM sensor when process performed on real data. Errors expressed as percentage of the range of values we can expect to observe in a scene containing case 2 waters.

3.15 SENSIAC Persistent Data Collection and Data Analysis

Sponsor(s): US Army Night Vision Laboratory (via the SENSIAC)

Research Team: Michael Richardson and David Messinger

Project Scope: Under this effort RIT is collecting imagery using the WASP sensor suite to help understand the role of multispectral imaging in persistent surveillance applications. The US Army Night Vision Laboratory is developing sensor requirements to meet a particular operational scenario need and this study is supporting these efforts. RIT collects imagery under various conditions and performs initial processing steps on the data before delivering a set of spatial / spectral target features to Georgia Tech Research Institute. GTRI is performing the data association trade study and analysis.

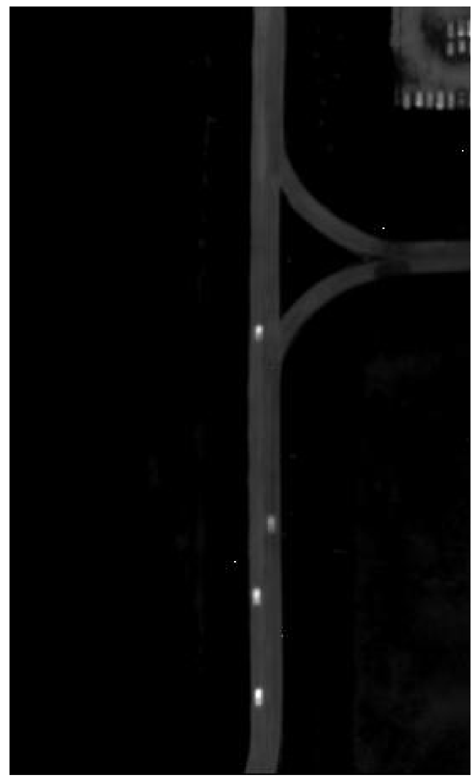


Figure 3.15-1: Moving vehicle signatures observed in the WASP LWIR camera in support of persistent surveillance research

Project Status: Several experiments were conducted during 2006-2007 in support of this program. Initially, static vehicles in the RIT parking lots were imaged from the airborne WASP platform. Target signatures were extracted from the imagery and delivered to Georgia Tech. A second collection was performed during January using vehicles moving around the “racetrack” entrance to the RIT campus. The goal was to study the thermal features from operating vehicles. An example LWIR image containing the moving targets is shown in Figure 3.15-1. Again, target signatures were processed and delivered to the Georgia Tech researchers. It was found that the addition of the visible spectral bands of the WASP sensor greatly enhanced the object identification algorithms. A report summarizing the first two experiments and the results was delivered to the Army Night Vision Laboratory in the spring of 2006. Future experiments simulating traffic intersections and the effects of solar illumination angle are planned for the summer of 2007.

3.16 Remote Sensing Data Assimilation with Physical Models of the Environment

3.16.1 Hydrodynamic and Water Quality Modeling

Sponsor(s): NOAA (Great Lakes Environmental Research Laboratory)

Research Team: Yan Li (Ph.D. student), Yushan Zhu (Ph.D student), Alvin Spivey (Ph.D student), Anthony Vodacek, Alfred Garrett (Affiliate Professor, SRNL)

Project Scope: Ontario Beach in Rochester, NY on Lake Ontario is subject to beach closings during the summer months due to excessive bacterial counts. The Monroe County Health Department has developed a decision model for beach closings based on a set of predictive indicators, most of which relate to flows from the Genesee River. We propose an integrated modeling system that will include a model of the Genesee River watershed, a hydrodynamic model to predict the fate of the Genesee River plume in Lake Ontario, measurements of water quality parameters in the river, and satellite remote sensing data and ground-based radar data for rainfall rates as data sources and validation of the watershed and circulation model (Figure 3.16.1-1). This model is expected to improve the accuracy of beach closure decisions, to decrease expenses related to monitoring water quality at the beach, and to provide data for devising management strategies that will decrease the frequency of beach closings.

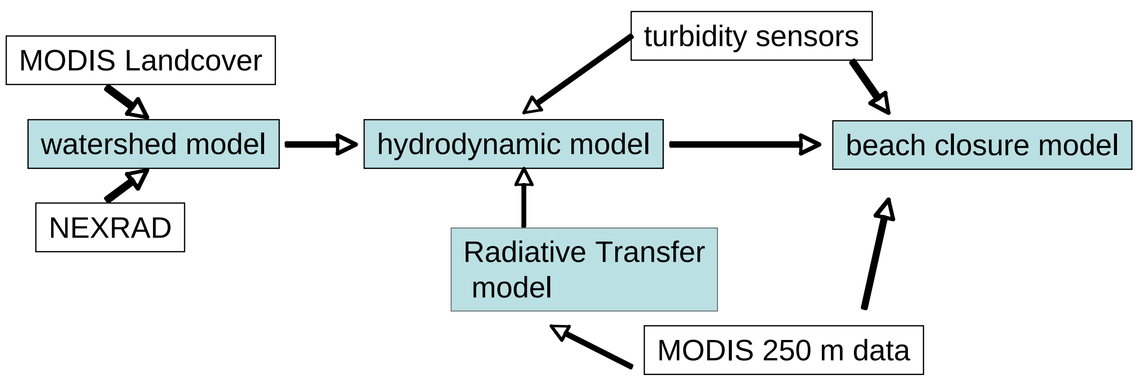


Figure 3.16.1-1: Flow chart of the proposed water quality monitoring model. The models are in blue boxes, the data in white boxes. The MODIS reflectance data and the turbidity sensor data are assimilated into the modeling system using an Ensemble Kalman Filter (EnKF). This data assimilation process updates the model as new data becomes available, thereby producing better predictions.

Project Status: The basic structure of the model has been built and tested for July/August 2003. An example of MODIS 250 m radiance data showing the plume of the Genesee River entering Lake Ontario (black) and being blown westward by the wind. The beach was closed on that day. An ensemble of 12 hydrodynamic model (ALGE) runs for the simulation period used random variations of the forcing data, specifically wind speed, wind direction, discharge, and TSS concentration, to produce 12 possible plume simulations over time. The simulated plume concentrations for sediment from the Genesee River were then used to predict the plume reflectance in each case by running the Hydrolight radiative transfer model for the conditions at the time the MODIS sensor was acquiring an image. This produced the model state that could be compared to the observation (MODIS) within the Ensemble Kalman Filter process.

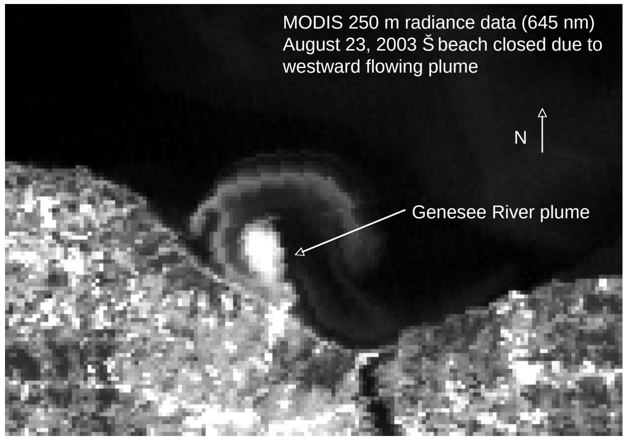


Figure 3.16.1-2: MODIS 645 nm radiance on a day that Ontario Beach was closed due to the westward flowing Genesee River plume.

The improvement in the simulation by assimilating the MODIS data is demonstrated for four days in August 2003 (Figure 3.16.1-3). The EnKF estimate is a better estimate of the plume behavior than the open-loop simulation with no data assimilation. We found that a threshold value of 45 mg L^{-1} of sediment in the water at the beach was a reasonable predictor of the actual determination of beach open/closed made by the County. Generally, when the predicted sediment concentration was above 45 mg L^{-1} the beach was closed and below that value it was open. Thus we can transform the modeling result into criteria useful for the beach closing decision process. Future work includes adding a hydrological model of the Genesee River watershed that will use satellite derived land cover and NEXRAD rainfall to predict sediment flow in the river. The initial EnKF results are discussed in detail in the Ph.D. dissertation of Yan Li, “An Integrated Water Quality Modeling System with Dynamic Remote Sensing Feedback.”

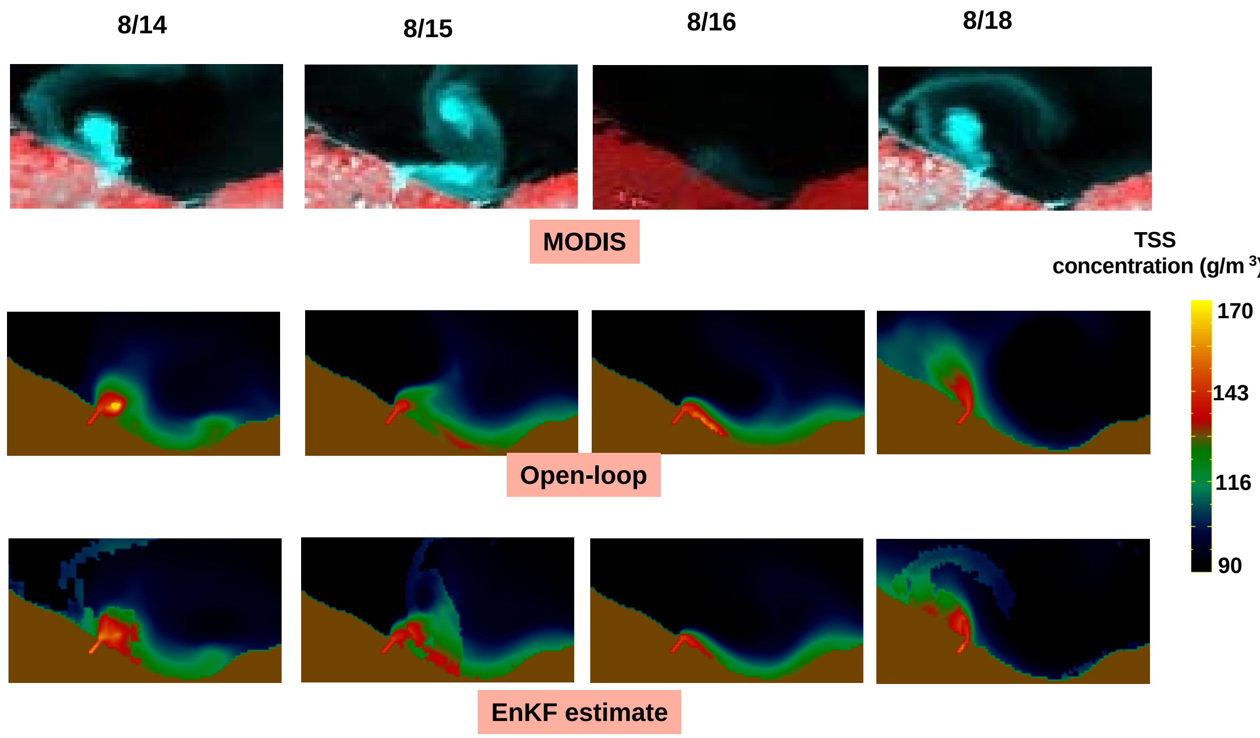


Figure 3.16.1-3: Comparison of satellite date and simulation results on four days. Top – MODIS data. Middle – Open-loop simulation result with no data assimilation. Bottom – Simulation with data assimilation via EnKF.

3.16.2 Fire Propagation Modeling

Sponsor(s): NSF

Research Team: Zhen Wang (Ph.D. student), Anthony Vodacek, Robert Kremens (LIAS), Carl Kelso (B.S. student)

Project Scope: This project is a collaboration with researchers at NCAR, U Kentucky, CU-Denver and TAMU. The goal of this project is to develop a dynamic data driven system for modeling the propagation of wild land fires. The end product will give wild land fire managers a tool for predicting the propagation of wild land fire with steering of the modeling results by data from ground sensors and remotely sensed data. RIT is developing the interface to use thermal imagers such as WASP or WASP-Lite as airborne data sources of fire location. Dr. Kremens is also continuing to develop ground sensor measurement capabilities and experimental data on the optical and thermal radiation emitted by fires. RIT is creating synthetic images from the model output to facilitate comparison to the ground sensor and airborne remote sensing data to provide steering of the model results. We are also using DIRSIG as a visualization tool for generating synthetic 3D fire scenes including the 3D structure of flames.

Project Status: Two years of additional funding for this project was granted in 2007. Ph.D. student Zhen Wang took the output of the fire propagation model and combined that with DIRSIG's atmospheric plume capabilities to generate 3D synthetic scenes of wildland fire as a fire would be observed by the WASP camera system (Figure 3.16.2-1). The method was validated by using the published Fire Radiative Energy (FRE) method to assess the radiance generated by DIRSIG in comparison to published estimates of FRE. Very good comparison was found, suggesting that the approaches used in generating the 3-D flame structure and 2-D fire history are very reasonable. This capability to generate synthetic data is a key component of the feedback process in which the fire propagation model output is steered according to the available remotely sensed images of a fire. In this case the fire propagation model output is used to generate a synthetic image that can then be directly compared to a real image. Carl Kelso, a computer engineering student worked with Dr. Kremens on improvements to the ground sensor systems used for determining the heat released during the passage of a wildfire and relating that to remote sensing measurement of fire radiation. Carl's work was supported by supplemental NSF Research Experience for Undergraduates (REU) funding. Further work on this project will use the 2003 Esperanza Fire in Southern California as a test case. Several sources of airborne and satellite thermal images are available for testing the data assimilation system.

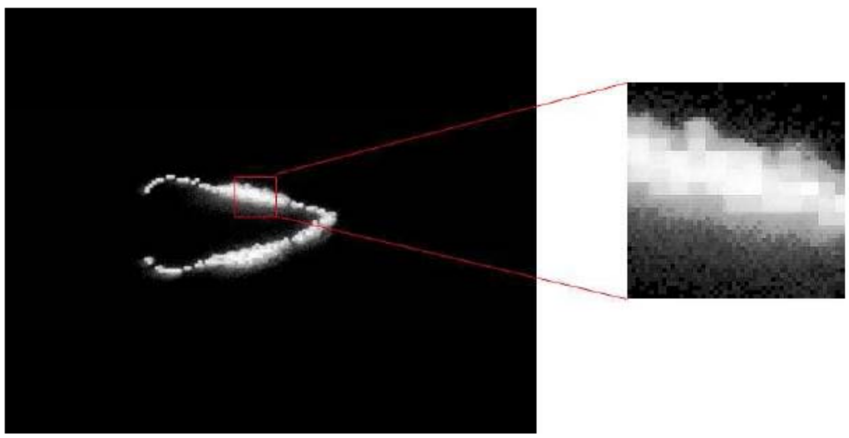


Figure 3.16.2-1: DIRSIG generated synthetic nighttime grassfire scene using the WASP sensor midwave infrared channel specifications. The scene radiance includes hot ground, 3-D flame structure, and reflection of the infrared radiation off the nearby ground surface.

3.17 Laboratory for Advanced Spectral Sensing (LASS)

Sponsors: Lockheed-Martin, NRO

Project Scope: The LASS was established to conduct research aimed at improving multi-dimensional remote sensing. The goal is to study the end-to-end process with an emphasis on looking at fundamental phenomenology and new sensing techniques. Because of the fundamental nature of this work the participants share in the funding and the results are shared with all sponsors.

Project Status: This year saw the continuation of several multiyear efforts including many which seek to improve the DIRSIG modeling environment and the initiation of some new thrusts in areas such as the role of spectral analysis in persistent surveillance and spectral quality metrics. The extensive range of LASS research tasks are summarized below.

3.17.1 MegaScene 2

Research Team: David Pogorzala, Eugenie Song (B.S. student), Jake Ward (Ph.D. student), Scott Brown

Task Scope: Simulated MegaScenes are comprehensive data sets that are intended to be widely used by the DIRSIG community. These scenes are recreations of real-world areas and are modeled to a high degree of spatial and spectral fidelity. The size of these scenes are several square kilometers, allowing the user to simulate data at oblique angles or along flight lines.

The first MegaScene was of a suburban region of Rochester, NY and contained many houses, grassy areas and paved surfaces. MegaScene 2, meant to act as a counterpart to this, is located in Trona, CA. This town is situated near Death Valley National Park and is a predominately arid, mountainous, desert-like region. A large industrial facility is located in the town which can be utilized in a number of ways in simulated imagery, from a chemical plant with gaseous plumes, to a nuclear power plant. The spatial fidelity of the majority of the scene is akin to that of MegaScene 1 (~1.0m), while the facility will be modeled at a resolution of ~0.5m. The dry, mountainous environment lends itself to utilizing new DIRSIG capabilities, such as inhomogeneous atmospheric models and new methods for recreating LWIR spatial-spectral variability.

Task Status: All data necessary for creating MegaScene 2 has been acquired. Two ground truth expeditions have been completed, resulting in the optical and thermal properties of the materials in the scene. Overhead imagery has been captured by the RIT WASP sensor system and will be used to drive the spatial and spectral variability in the terrain.

Significant work has been done recently on the spatial aspects of the scene. At this point nearly all objects have been geometrically modeled in a CAD environment. In addition, these CAD models have been assembled into a coherent “scene” atop a facetized terrain model. Each building and house has been placed on the terrain in its real-world UTM coordinates, resulting in an accurate recreation of the town of Trona and the surrounding areas. The incorporation of the terrain has resulted in the need to modify the original CAD models of the facility to account for variations in the z-height of various objects.

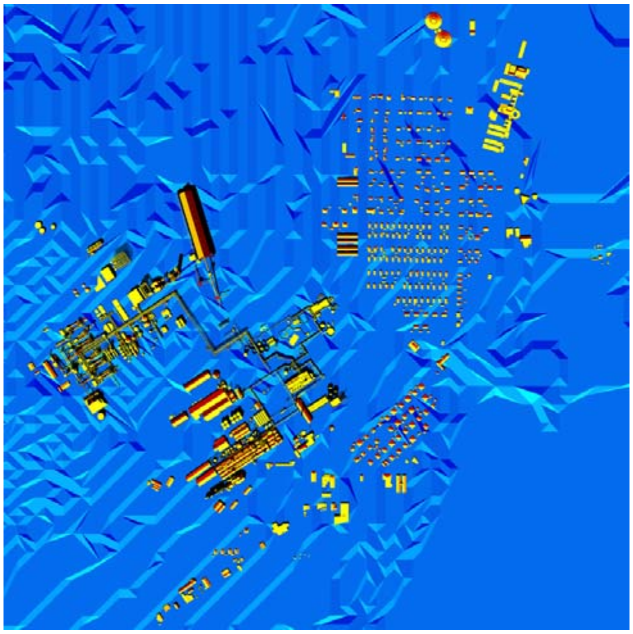


Figure 3.17.1-1: Overhead RGB rendering of MegaScene 2.

A preliminary DIRSIG rendering of a portion of the MegaScene 2 area, centered on the industrial facility, is shown in Figure 3.17.1-1. The materials attributed to the geometry are temporary surrogates A shiny blue metal material has been used for the terrain and a orange-colored tank has been applied to all other geometry. These materials were chosen for their vividness and for the significant contrast between the appearance of the two materials in the final scene. A second, oblique rendering of the scene is shown in Figure 3.17.1-2. This image highlights the mountainous terrain present in the scene. Also evident in this figure is a number of “floating” buildings, illustrating the problems encountered with the facility when the terrain was introduced.

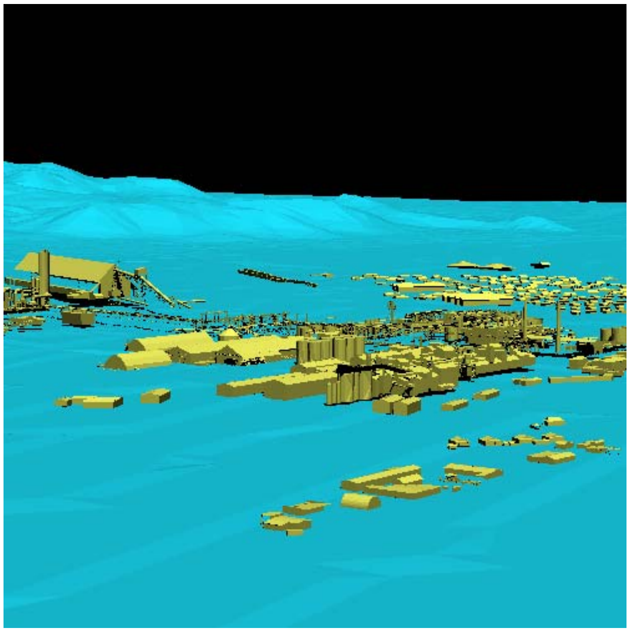


Figure 3.17.1-2: Oblique RGB rendering of MegaScene 2.

3.17.2 Polarimetric Imaging

<u>Research Team:</u> David Messinger, Chabitha Devaraj (Ph.D. student), David Pogorzala, Scott Brown

<u>Task Scope:</u> The goal of this research is to better our understanding of polarimetric phenomenology in regards to remote sensing, to learn and overcome the challenges involved with simulating imagery acquired with a polarized sensor, and to develop tools to exploit polarized imagery.

<u>Task Status:</u> Several studies have been performed to help address the goals outlined above. The first experiment was aimed at validating the implementation of the polarized version of MODTRAN in DIRSIG. The WASP-Lite sensor system, developed at RIT, was outfitted with a series of polarizing filters. The sensor was then used to image the sky in several locations relative to the sun. The phenomenology observed in this data collect was then verified with an extensive collection of simulations in DIRSIG. A scene was constructed consisting of simple, three-dimensional objects in the shapes of letters corresponding to the compass directions (N, E, S, W). These letters were then arranged on a flat terrain with the “N” to the north, the “E” to the east, and so on. These objects served as a visual reference as to which direction the sensor was pointed. Objects in the shapes of “+X”, “-X”, “+Y” and “-Y” were also added to help reference the scene in DIRSIG coordinates. Finally, a three-dimensional cube was inserted in the scene directly above the origin to serve as an indication of an elevation angle of 90 degrees. This scene was simulated with a pushbroom sensor that was located at the origin, turned on its side, and was rotated on the z-axis for 360 degrees, starting and ending facing north (+Y). The resulting image, shown in RGB in Figure 3.17.2-1, is a view of the entire sky. The cube is visible as an elongated strip near the top of the image.

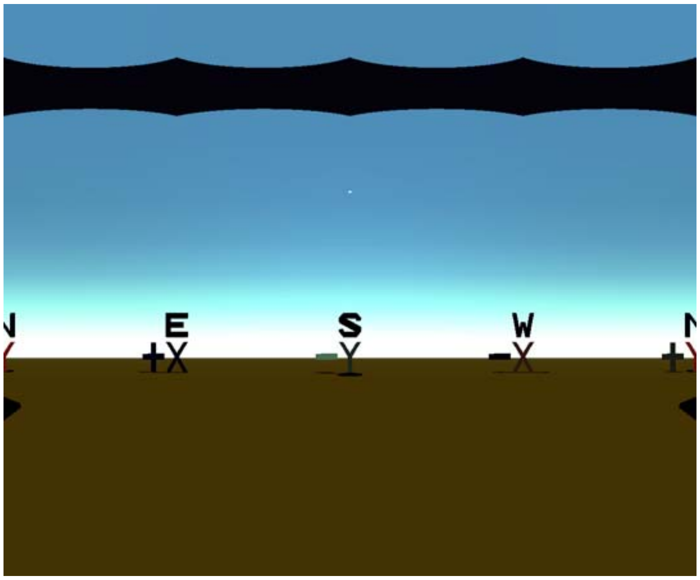


Figure 3.17.2-1: RGB rendering of the skydome simulations.

This scene was then simulated with polarized outputs from MODTRAN for several combinations of the time-of-day, the visibility of the atmosphere, and the elevation angle of the sun. Of the outputs from these simulations, the two that are most effective at encapsulating the polarized behavior of the atmosphere are the Degree of Polarization (DOP) and the Angle of Polarization (AOP). Two sets of these images are shown in Figures 3.17.2-2 and 3. The sun is at a high elevation angle in the first set and a low angle in the second. As expected, the DOP is lowest in the area around the sun and highest in areas orthogonal to it.

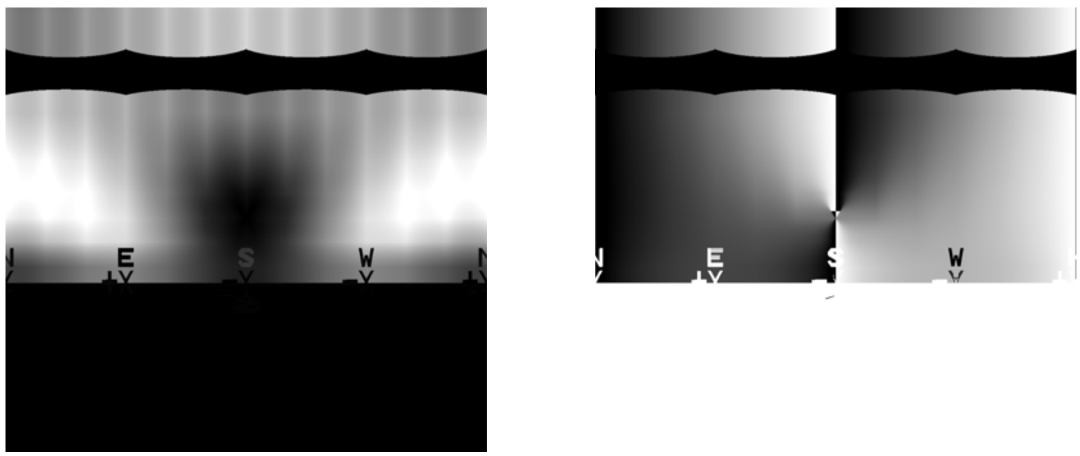


Figure 3.17.2-2: DIRSIG-generated DOP (left) and AOP images of a polarized sky dome with the sun at a low elevation angle.

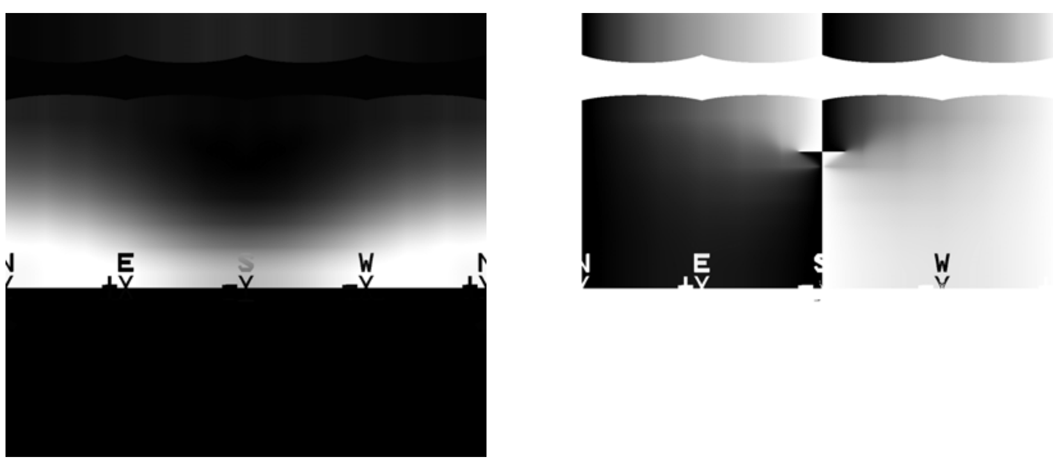


Figure 3.17.2-3: DIRSIG-generated DOP (left) and AOP (right) images of a polarized sky dome with the sun at a high elevation angle.

A laboratory study was also conducted to verify the geometric coordinate transformations used in the simulation tool. This study used a controlled illumination source and camera with a rotatable polarization filter wheel to show that the surface reflection geometry, critical to accurate polarimetric image modelling, was correct.

The final study that was performed attempted to tie together the previous validations to recreate a simple, natural, outdoor scene in DIRSIG. A small test area on the RIT campus was imaged from the roof of the Center for Imaging Science by the WASP-Lite sensor system outfitted with polarizing filters. This scene, consisting of an area of grass, two trees, a fire hydrant, and asphalt, was then reconstructed in the DIRSIG environment. At the time of the data collect, the asphalt had been partially removed during a repaving process, resulting in long grooves. The final DIRSIG images are shown as Stokes images in Figure 3.17.2-4.

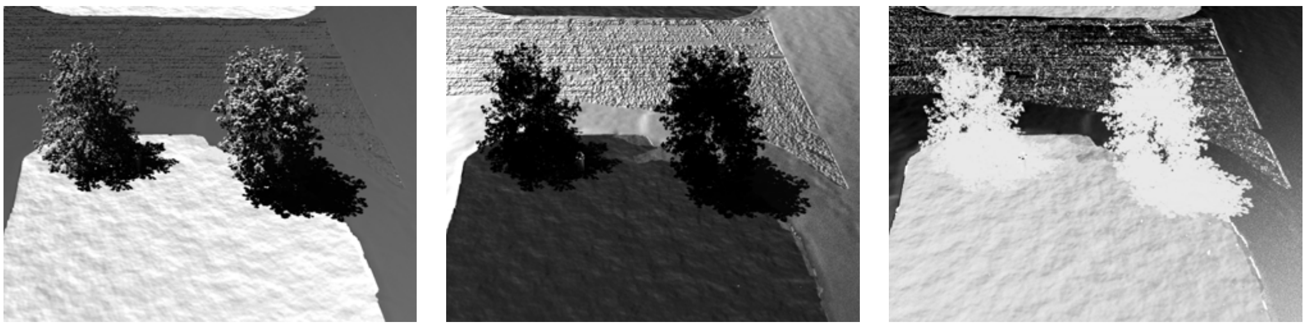


Figure 3.17.2-4: Polarimetric DIRSIG imagery; S0 (left), S1 (center) and S2 (right).

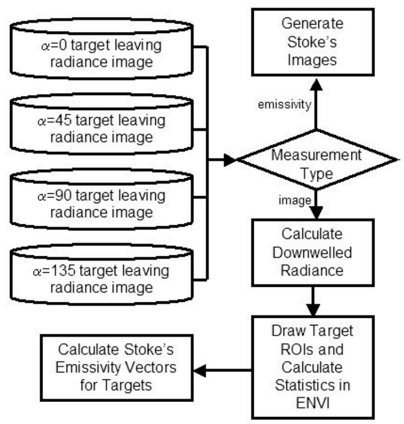
3.17.3 Thermal Polarimetric Imaging BRDF Measurement

Research Team: Michael Gartley (Ph.D. student), Scott Brown, Niek Sanders, John Schott

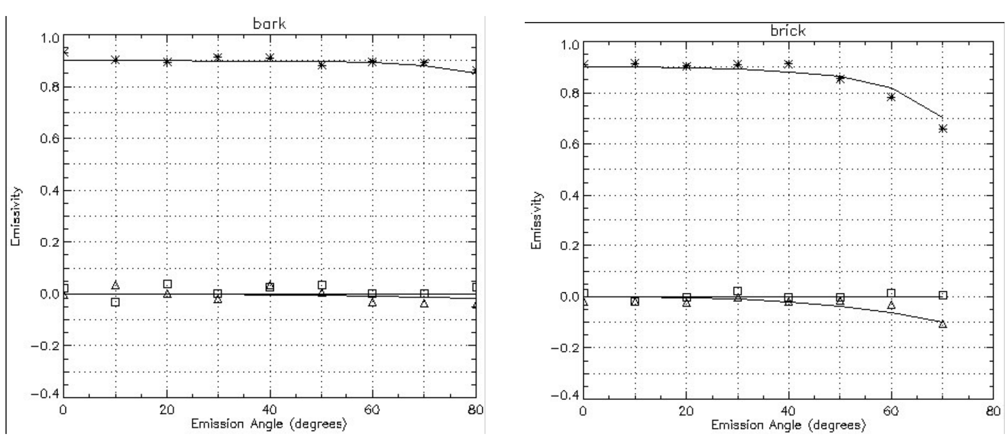
Project Scope: This task is aimed at development and implementation of a thermal infrared emissive polarization modeling capability in the DIRSIG model.

Project Status: The project is nearing completion (expected in Fall 2007). A methodology has been developed to model the emissive polarimetric behavior based on the bidirectional reflection distribution function (BRDF) and the use of Kirchoff's Law to convert the integrated hemispheric reflectance to emissivity. To evaluate the method an approach to measurement of polarimetric emissivity has been developed that uses a longwave infrared camera and a wire grid polarizer (see Figures 3.17.3-1 and -2). Figure 3.17.3-3 shows a fit of measured data to modeled data illustrating how the BRDF models can effectively reproduce the measured data. Figure 3.17.3-4 shows the initial testing of the DIRSIG implementation on a sphere. This comparison of real and simulated data illustrates that the initial implementation of the magnitude of the polarization degree of polarization (DOP), and the angular orientation of the polarization simulation are in agreement with observation.

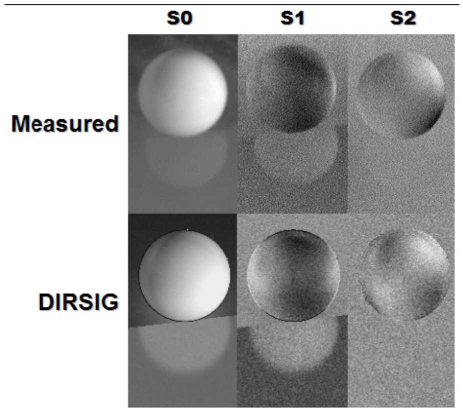
3.17.3-1: **EZTherm LWIR camera and IR wire grid polarizer.**



3.17.3-2: Processing paths for Stoke's generated imagery and emissivity measurements.



3.17.3-3: Emissivity model (line) fit to experimentally measured emmissivity (points) for tree bark (left) and brick (right).



3.17.3-4: Measured and DIRSIG images showing a sphere sitting on snow with a glossy plate in front with a sun elevation of 18 degrees.

3.17.4 LIDAR Modeling and Application

Sponsor(s): Lockheed Martin

Research Team: Scott Brown and Niek Sanders

Project Scope:
Continue to evolve and develop the laser remote sensing capability introduced into DIRSIG. This includes the ability to model topographic LADAR and atmospheric LIDAR.

Project Status:
During the past year, several limitations of the DIRSIG model were addressed and improvements made to support enhanced capabilities. These include the following:

- Improvements in analytical backscatter returns including a suite of unit tests.
- Improvements to resolve problems with slant looking, horizontal looking and up looking geometries.
- Improvements to the distributed tool that performs "detection and geolocation" of the DIRSIG produced photon arrival cubes. This included an improved detection model for Geiger-Mode Avalanche Photo Diode (GmAPD) devices that handles quantum efficiency and spontaneous noise generation. The improved tool also allows platform and scanning noise (uncertainty) to be incorporated during this stage of the overall simulation.
- Updates and improvements to available demonstration scenes and configurations.

3.17.5 Persistence Surveillance

Research Team: Andrew Adams (Ph.D. student), Niek Sanders, John Schott

Project Scope: This project is intended to develop a capability to allow performance tradeoffs to be conducted between sample frequency, number of bands, spatial resolution and signal-to-noise in persistence surveillance sensors. The expectation is that use of multiband data can significantly increase the time between samples thus freeing up imaging resources to keep multiple target sites under surveillance with a single sensor.

Project Status: An approach to detect and localize change in multitemporal image frames has been identified that is appropriate for both single band and multiple band data. A synthetic image has been generated in DIRSIG that incorporates a variety of moving targets (vehicles and people) and increasing levels of complexity (obscuration, crossing and dismounts) that will be used to test the proposed approaches (see Figure 3.17.5-1a). Initial tests on a single band image have demonstrated that targets can be isolated with the baseline algorithm (see Figure 3.17.5-1b). Future work will focus on implementation and testing of the multiband data.

a) b)

3.17.5-1: DIRSIG Movie a: full resolution (1024x1024), b: motion detection results (Single Band—Green, 256x256)

3.17.6 Spectral Target Detection Algorithmic Comparison

Research Team: Manuel Ferdinandus (Masters' student), John Schott, David Messinger

Project Scope: Target detection algorithms for use in hyperspectral imagery rely on accurate estimation and characterization of the "background" (*i.e.*, not target) pixels in the image. Typically this is done using simple first and second order statistics (means and covariances) to "train" the algorithm. There are several methods one can use to choose which set of image pixels to use in training. This project seeks to understand which methods are most appropriate for use in a given image or with a given target signature. The ultimate goal is to understand why a particular method failed, and potentially to understand how to characterize an image / target combination as being potentially either difficult or easy (in a quantitative sense) to detect. Here, a "target injection” method (based on the work of Dr. Stanley Rotman) was used to analyze not only image pixels containing known targets, but the entire image regardless of the presence of real targets on the ground. This method allows for a more general analysis of an entire image to be conducted and indicates in which pixels a target may be particularly difficult (or easy to detect).

Project Status: This project will be completed in the summer of 2007. Visualization methods to qualitatively assess the various background characterization methods have been developed and an example is shown in Figure 3.17.6-1. Here, the per pixel color coding indicates which of the background characterization methods tested worked best for that pixel. The methods tested use various sets of pixels (grouped together by their spectral signatures) to estimate either the background mean and / or covariance.

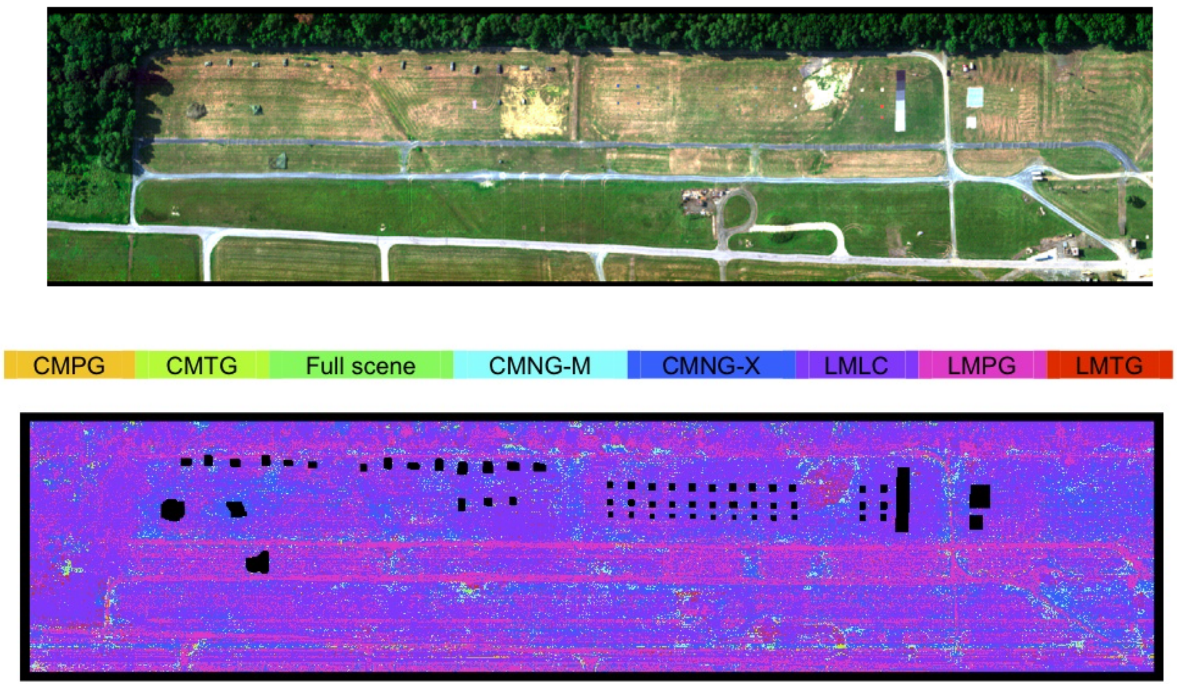


Figure 3.17.6-1: (top) RGB of the test scene. (bottom) Example visualization of the best background characterization method for a particular target / image pair. Here, “best” is determined by the minimum amount of sub-pixel fill factor required for detection. Black areas indicate where man-made targets have been masked out.

In this case the “best” method for a given pixel is that algorithm that could detect the target at the lowest sub-pixel fill factor (the target injection method allows the user to simulate how sub-pixel the target is). Note that different methods are best for large open areas or along transition regions. In this case, the local estimation of both the mean and covariance (LMLC) is optimal but this is not the case for all targets and images tested. Ongoing work is investigating other image / target pairs to attempt to identify correlations and patterns.

3.17.7 Background Texture Research (visible and thermal)

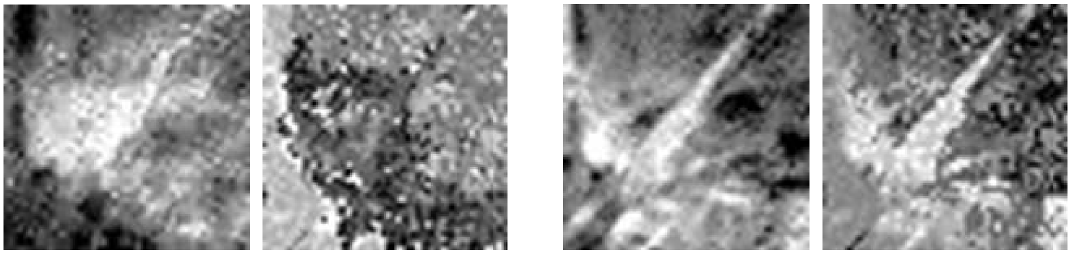
Research Team: Jason Ward (Ph.D. student), David Pogorzala, John Schott

Project Scope: This project is aimed at improving the texture in synthetic scenes. This includes implementing improved methods of incorporating reflective texture in existing DIRSIG scenes. Texture is a major factor impacting both the visual appearance and the overall scene statistics. Lack of adequate texture has been identified as one of the serious limits to using synthetic scenes for realistic target detection algorithm development.

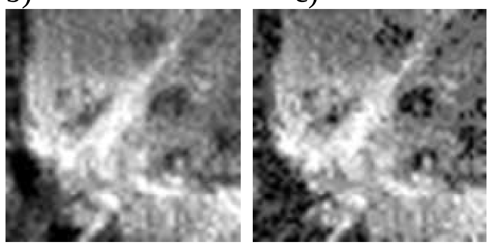
Project Status: Three methods of texture generation developed and tested on earlier efforts have been implemented in DIRSIG and applied to a region of RIT's MegaScene I. The methods shown in Figure 3.17.7-1 are the traditional single band texture metric, a modified multiband version of the original method and a significantly improved method based on fractional mixture maps. This last method has been shown to both visually and quantitatively improve the texture statistics in an image. However, it requires the user to have fractional mixture maps of the materials within a class (e.g. green vegetation and soil within the grass field class). These methods can be employed on a class by class basis in the new version of DIRSIG and the mixture mapping approach will be employed where possible on MegaScene II.

3.17.7-1: DIRSIG generated scenes showing texture results using the traditional single band approach, the multiband approach and (for a different set of conditions) the fractional mixing model approach.

Texture in thermal images is a much more complex task. This is because the texture is not just a function of observable (in band) surface properties (i.e. variation in reflectivity or emissivity) but also of temperature variation which is a function of solar absorptivity, surface orientation, shadowing and bulk thermal properties. To deal with these variations DIRSIG is being improved to allow use of texture maps to control bulk thermal properties. In addition an ongoing research project is aimed at developing methods to build these bulk property texture maps based on analysis of multitemporal thermal imagery. Some preliminary results from this approach are shown in Figure 3.17.7-2. These images are the result of model based fits of the DIRSIG thermal model with varying bulk materials properties within a class to the observed thermal images of the class. The results show actual images and the predicted images based on fits to the model.



a) b) c) d)



e) f)

3.17.7-2: LWIR 50 x 50 Pixel Example Imagery: (a) Original 5 AM, (b) Simulated 5 AM, (c) Original 11 AM, (d) Simulated 11 AM, (e) Original 5 PM, (f) Simulated 5 PM

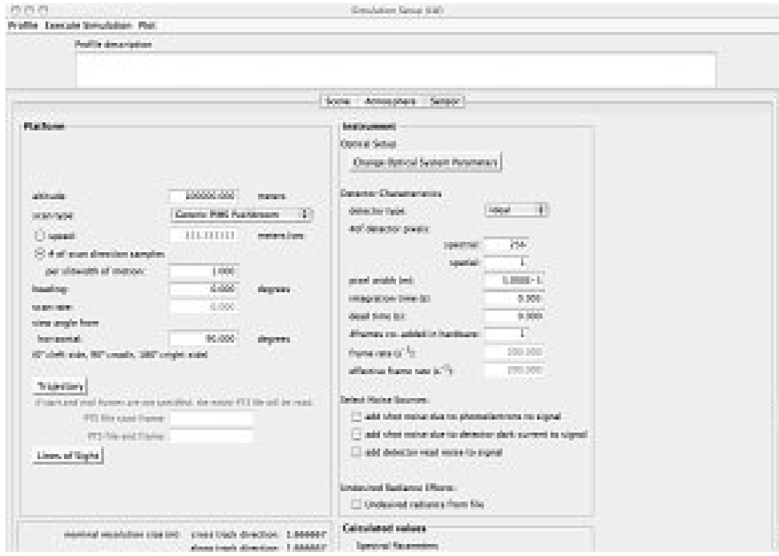
3.17.8 DIRSIG Plume/Sensor Integration (QUIC and PIMS)

Sponsor(s): Los Alamos National Laboratory (LANL)

Research Team: Scott Brown and Niek Sanders

Project Scope: The aim of this project was to integrate the advanced PIMS sensor model from Los Alamos National Laboratory (LANL) with the sensor-reaching radiance results produced by DIRSIG.

Project Status: This collaboration has produced an initial version of PIMS capable of automatically and directly calling DIRSIG. This project has simplified combining the PIMS and DIRSIG models.



3.17.8-1: A screenshot of the PIMS user interface.

In support of this project, an "Interactive Mode" has been added to DIRSIG. It allows users to bypass DIRSIG's platform and sensor models, communicating directly with the radiometry engine. This interface supports human-friendly plaintext, computer-friendly XML, and high-performance binary output. It can be used to tightly integrate external models with DIRSIG, and to integrate DIRSIG with systems engineering tool chains. Furthermore, the new functionality and interface is fully documented in the DIRSIG manual.

3.17.9 Improved DIRSIG User Interface and NetDIRSIG

Sponsor(s): National Reconnaissance Office (NRO)

Research Team: Scott Brown and Paul Lee

Project Scope:
Primary goal is to create a user interface for DIRSIG that allows non-traditional (non-expert) users to generate data with the model. This software client tool is designed to be lightweight, easy to acquire and easy to use. The tool is also network enabled. The user isn't required to install a traditional full copy of DIRSIG on their machine; rather the client tool interacts with a network accessible repository of the DIRSIG inputs on a remote server. This client/server model simplifies and centralizes the maintenance of the model inputs within an organization or within an inter-organization workspace. The client/server approach allows the "heavy computational lifting" of DIRSIG simulations to be offloaded to the remote server which frees up the client machine. The completed simulation products (imagery) are made available on the server for remote download.

The long-term goal of this project is the creation of an extensive set of user interfaces that allow many of the untapped features in DIRSIG4 to be discovered and exercised by the users.

Project Status:
During the past year, the first version of this tool was completed and demonstrated. However, since documentation for installation of the client software, documentation installation of the server software and creation and documentation of the new data descriptions have not been complete, the tool has not been widely distributed at this time. These tasks will be completed during 2008.

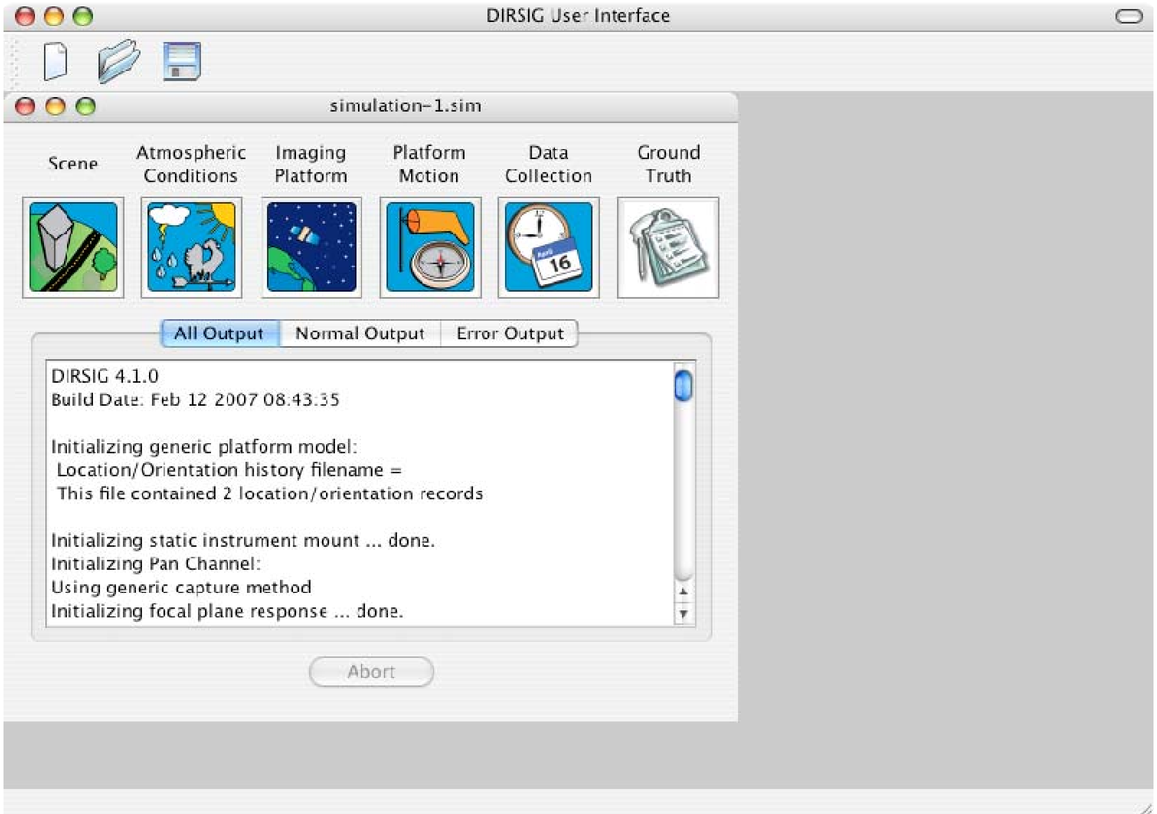


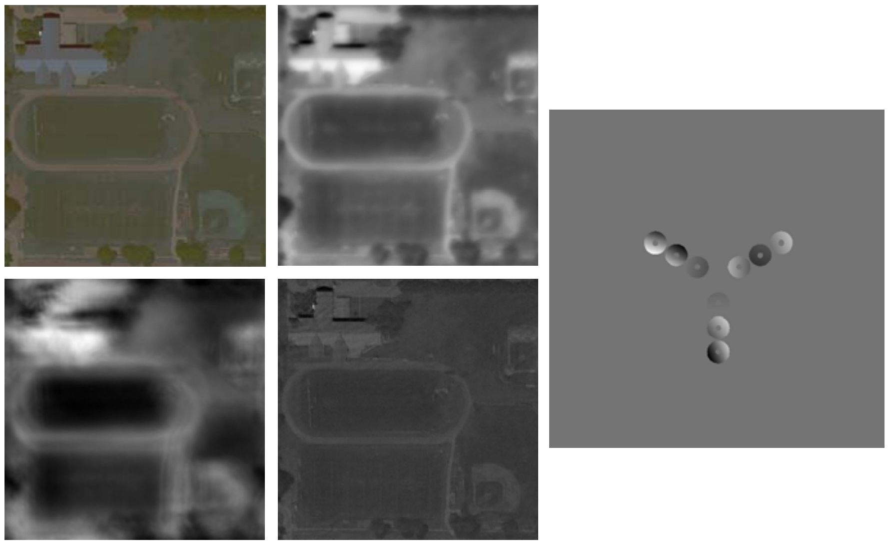
Figure 3.17.9-1: A screenshot of the new graphical user interface running a simulation.

3.17.10 Sparse/segmented Aperture Image Quality Modeling

Research Team: Brian Daniel (Ph.D. student), Jason Smith (Ph.D. student), John Schott

Project Scope: This project is aimed at extending RIT's efforts to model and evaluate image quality associated with sparse and distributed apertures. Most of the work in this area has been associated with astronomy where the targets are approximately point sources and spectrally well behaved (i.e. gray). Earlier work at RIT has shown that the spectral nature of extended scenes can introduce image artifacts in restored images from sparse aperture systems that would not have been predicted using the gray world models commonly used to predict image quality.

Project Status: This effort is focused on evaluating the impact of using phase retrieval algorithms on restored image quality from sparse and segmented aperture systems. In particular the impact on spectrally diverse extended images is of interest. Methods to generate in focus and out of focus images based on full spectral modeling of extended scenes have been developed (see Figure 3.17.10-1). Ongoing efforts are focused on implementation of a phase diversity retrieval algorithm to estimate the optical path difference induced phase distortions in the images and on methods to estimate image quality in the restored images.



3.17.10-1: Initial simulations of phase diversity model showing (clockwise from top left) input image, in focus image through sparse aperture telescope, pupil function of telescope showing optical path differences in shades of gray, restored image and defocused image.

3.17.11 Spectral Image Utility

Research Team: Marcus Stefanou (Ph.D. Student) and John Kerekes

Project Scope: This project is an effort toward the development of quantitative metrics for spectral image quality analogous to the use of the National Imagery Interpretability Rating Scale (NIIRS) and the associated General Image Quality Equation (GIQE).

Project Status: The project has two main thrusts. First, the domain of image quality as it relates to spectral imagery and its application is being surveyed and a taxonomic structure of components and characteristics developed. Second, an initial approach is being developed for characterizing the utility of a spectral image in the context of target detection.

Figure 3.17.11-1 graphically illustrates the elements of a remote sensing spectral imaging system including the scene, the atmosphere, the sensor and the processing performed leading to the desired information. Spectral image quality can be thought of has having two components contributing to a measure of quality: image fidelity and image utility.

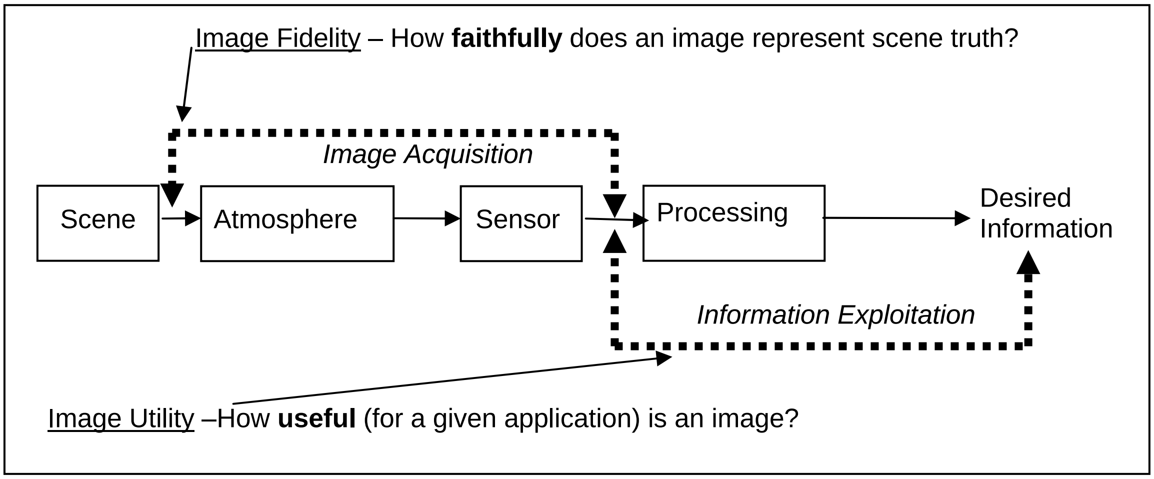


Figure 3.17.11-1: Components of spectral image quality: fidelity and utility.

As shown in the figure, image fidelity refers to the ability of the sensor to faithfully capture and represent all important features in the scene. Image utility refers to the usefulness of the image for a desired application.

This project is focusing on developing methods for the quantitative description of spectral image utility in the context of target detection. The approach is to start with a given spectral image as collected or retrieved from a database. The question we are exploring then is, can one provide a quantitative metric to predict how useful this image can be in detecting a specified target.

The approach is to explore various methods of parametrically representing the salient spectral features in a spectral image and then use those parameters to predict target detection performance. Figure 3.17.11-2 shows an example comparison between actual performance for detecting a subpixel target in a given image compared to performance predicted by three different parametric models. In this particular case, the T-distribution model compares best with the actual performance.

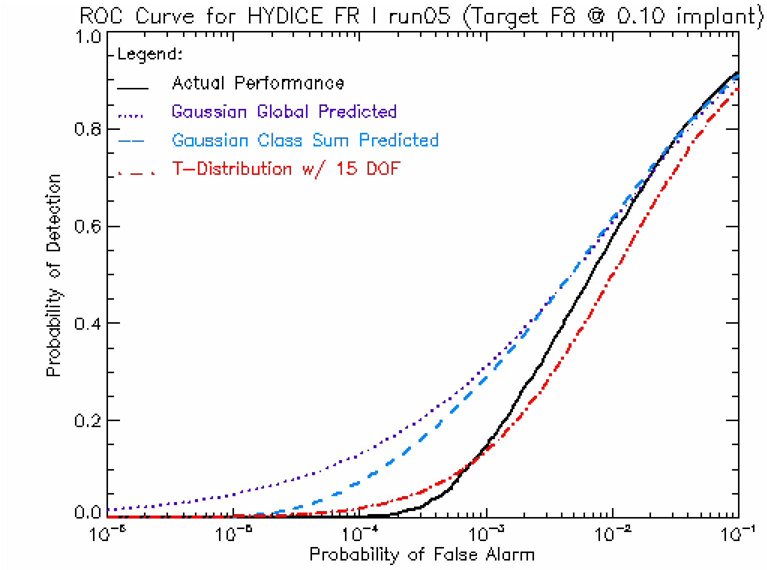


Figure 3.17.11-2: ROC curve comparing achieved performance with various model-based predictions for detecting a specified subpixel target in a given spectral image.

4.0 RIT Funded Core Research

4.1 DIRSIG Infrastructure

Sponsor(s): Internally funded

Research Team: Scott Brown, Niek Sanders, Mike Gartley and Adam Goodenough (Ph.D. student)

Project Scope:
In addition to the sponsored research projects that address the enhancement of the DIRSIG model, RIT has been slowly increasing the amount of staff time spent working on infrastructural DIRSIG development. This ranges from the purchasing and maintenance of the server used to distribute the model to the general maintenance of the software and supporting software development systems. Historically, the creation of the new and improved DIRSIG4 model was largely funded internally.

Project Status:
One of the fundamental funding streams for DIRSIG core development has been various sources of RIT internal funding. The primary source of this funding has become the DIRSIG Training Courses, which was offered on three (3) different occasions during the 2007 calendar.

During most of the past year, the development team focused on Release 4.1. The important milestones of this release cycle were significant amounts of radiometry improvements resulting from verifications against previous generations of DIRSIG and analytical solutions. Another important focus was the expansion of the unit testing facility to ensure the correct operation on the low-level code components over time. At this time, the unit-testing framework performs 1,400+ individual tests. The verification of the model fitness with the unit-testing tool is now an integral part of the software release process and the tool is distributed to the users as a way to verify the software installation process. Important new features added to DIRSIG4 in 2007 included the addition of secondary (man-made) sources and the incorporation of the "participating medium" tools developed by Adam Goodenough for his littoral zone modeling. The improvements made by Mike Gartley during his Ph.D. work to support emissive polarization simulation have also made their way into the DIRSIG4 releases.

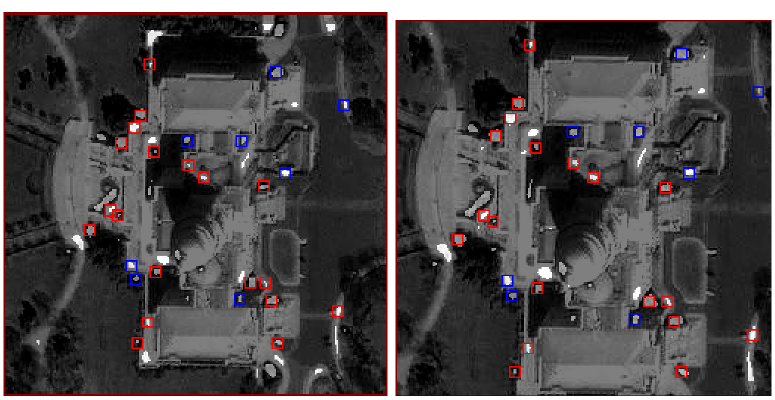
In 2008, the development team will continue to provide the user community with improved versions of the DIRSIG model with an increased focus on release testing, verification and validation. This upcoming year will also see the transition to the new user interfaces developed (in part) under the NetDIRSIG effort and revised training and documentation to educate the user community.

4.2 Facility/Process Modeling

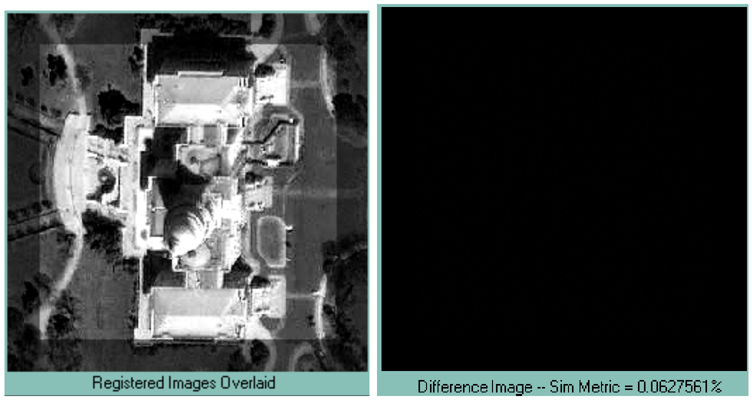
Research Team: Jacob Clements (Ph.D. student), John Schott, Michael Richardson, Scott Brown, David Messinger

Project Scope: This project represents the initiation of a long term effort to develop and evaluate new approaches to data processing, database management (metadata tagging) and analysis of multisensor-multimodal data with an aim of radically changing the way data are analyzed and the types of information that can be extracted from multiple ways to "touch" a target.

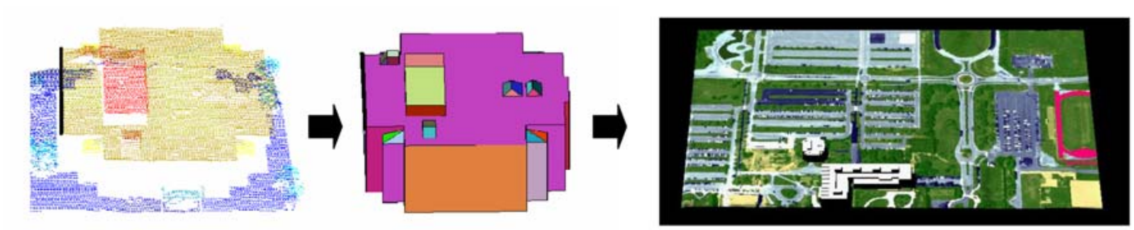
Project Status: The initial thrusts for the project fall into three categories. One aims to develop ways to register multisensor data using 3 dimensional geometric models of the world. This effort will be an extension of earlier efforts at RIT to develop semi-autonomous methods for registering 2D image data and methods to construct geometric target models from 3D LIDAR point clouds (see Figure 4.2-1 (Walli 2003) and 4.2-2 (Lach and Kerekes 2007)). The 3D registration task will be initiated Fall (2007).



4.2-1a: The image crop has induced a -25 pixel shift in x & y for the inverse transform sampling. Automated control points are highlighted.



4.2-1b: Confirming the registration results through visual inspection of overlaid and original images. The dark image to the left is the difference maps showing very low signals (i.e. complete registration).



4.2-2: Use of LIDAR point clouds (left) to form facetized model (middle) that can be registered to EO imagery or used to generate simulated images (right).

A second thrust category is aimed at ways to organize and visualize multisensor-multitemporal data. It is common for us to have many measurements of a location of interest. These may be overhead images from a range of platforms and sensors acquired over a wide time history, ground photos, data from other sensor types and text and graphical data. A focus for this research is to develop ways to allow an analyst to seamlessly interact with these various data types. One of the initial questions will focus on issues around how well the data need to be registered and how to project the data in space and time in ways the analyst can efficiently visualize and analyze. These first two thrusts will feed each other with the registration task providing better data to the visualization task and the visualization task helping to set various requirements on the registration task. As part of this visualization and interaction task we expect to engage RIT's Computer Gaming department to try to bring new perspectives and approaches to ways to interact with data. Our goal is to totally emerse the analyst in the data using the advanced hardware and software available on state of the art general purpose computers. This task has as its initial focus a water treatment plant that falls in the RIT MegaScene site that is adjacent to the Camp Eastman site that RIT regularly uses for field tests. As a result, we already have extensive coverage of the site with a variety of sensors and are continuing to acquire data on a regular basis (Figure 4.2-3 shows a variety of image samples). This thrust area is just getting started with an initial emphasis on identifying potential commercial software to support data manipulation and interaction and organization of existing data.

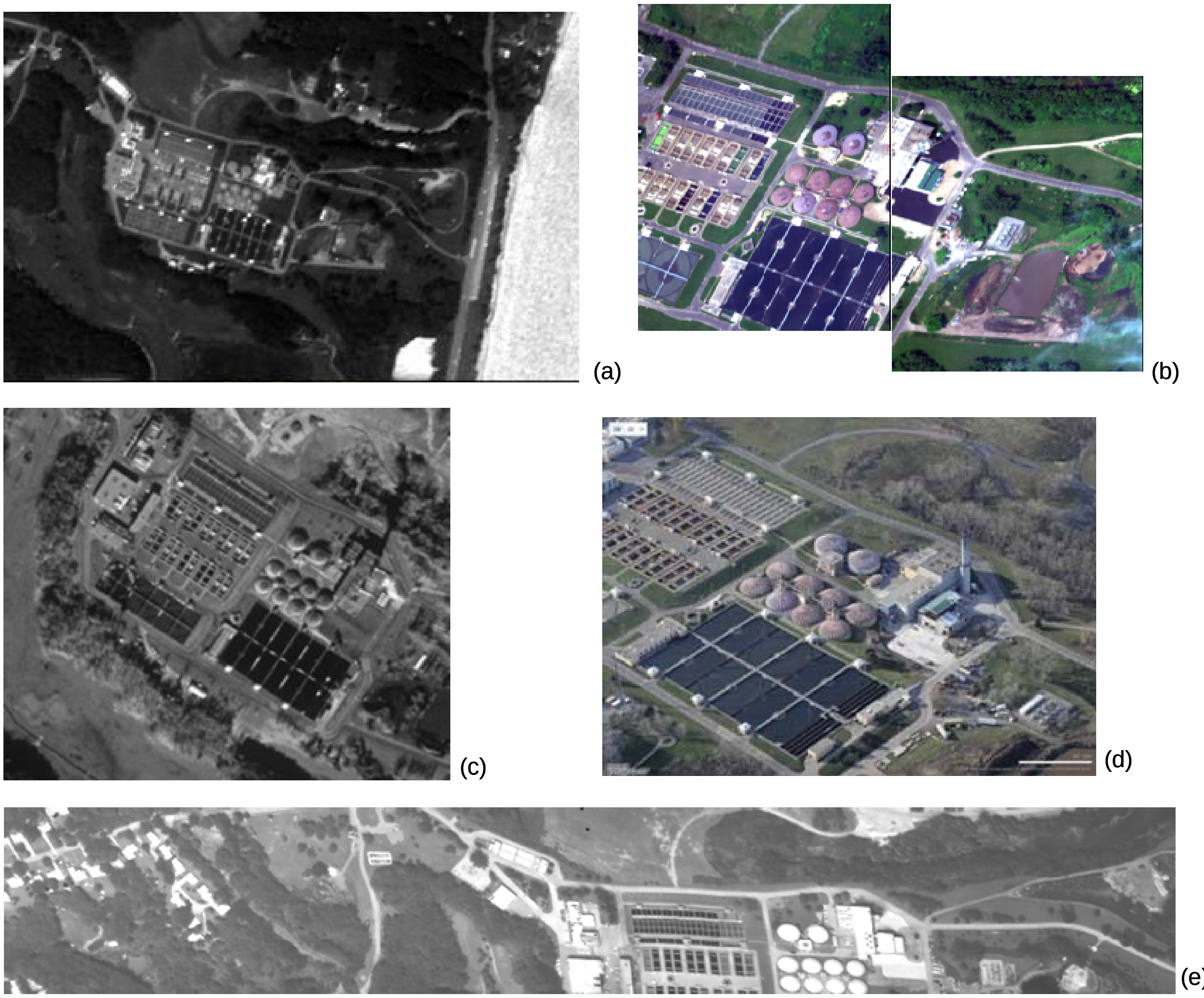


Figure 4.2-3: Multi-sensor Image Data over the VanLare Water Treatment Facility (a) (b), Compass RGB Image (c) (d) Oblique RGB Color (image courtesy of Pictometry International) (e) SEBAS LWIR Image

The third thrust area is focused on efforts to merge data and models in a fashion that blurs the distinction between data and models. A good example of the goal here is the meteorological community where we have a wide variety of surface, satellite imaging and non imaging sensors and forecast models that are used collectively to extract meteorological information and make informed forecast (predictions of behavior). With this as a guide we are looking to merge 3D geometric site models with image and non image data and process models (e.g. models of processes associated with a particular site) to allow an analyst ways to interact with the data and the models to address more complex intelligence questions. For example, I know what the site is in general (e.g. chemical plant) but not what it is producing (compound x, y, z), how much, when, where it is going, or what confidence do I have (i.e. what other hypothesis might be valid and how could I deny or confirm an alternate hypothesis)? Clearly the registration and visualization thrusts are critical enablers to the data/model fusion tasks. The initial efforts on this task have been to identify the water treatment site described above as an initial study site. We have developed a working relationship with the facility operators and are beginning to develop conceptual models for various processes at the site. We already have an initial DIRSIG model of the site (see Figure 4.2-4), however, we suspect a more rigorous site model may be required to support this effort. Ongoing efforts are aimed at defining signatures associated with various process models and definition of ways to merge various data sources into a common data/model environment. These include GIS data, a wide range of overhead images, ground photos, text data, plant process models, thermodynamic models, etc….

Figure 4.2-4: DIRSIG image (left) and real image (right) of study site.

The goal of this thrust area is to develop an initial demonstration of a fused data/process model of the site which can be used to evaluate hypothesis concerning various operating conditions for a facility, including confidence estimates.

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5.0 Publications

5.1 Books and Journal Articles

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6.0 DIRS Student Thesis and Capstone Projects

In recognition of the work of our students over the years, we list not only the current capstone projects, but also the work of all the students who worked on DIRS projects since the laboratory was organized in 1981.

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Lawrence Maver, 1983, "The effects of shadow visibility on image interpretability"
George Grogan, 1983, "A model to predict the reflectance from a concrete surface as a function of the sun-object-image angular relationship"
Ian. Macleod, 1984, "An airborne thermal remote sensing calibration technique" Canadian Forces
William Volchok, 1985, "A study of multispectral temporal scene normalization using pseudo-invariant features, applied to Landsat TM imagery"
Joseph Biegel, 1986, "Evaluation of quantitative aerial thermography"
Tim Hawes, 1987, "Land cover classification of Landsat thematic mapper images using pseudo-invariant feature normalization applied to change detection" U.S. Air Force
Carl Salvaggio, 1987, "Automated segmentation of urban features from Landsat thematic mapper imagery for use in pseudo-invariant feature temporal image normalization"
Wayne Farrell, 1987, “Investigation of the Accuracy of Array Radiometry for Measuring Pulsed Radiation Sources” Canadian Forces
John Francis, 1989, "Pixel-by-pixel reduction of atmospheric haze effects in multispectral digital imagery"
Denis Robert, 1989, "Textural features for classification of images" Canadian Forces
Jan North, 1989, "Fourier image synthesis and slope spectrum analysis"
Michael Davis, 1990, "Bidirectional spectral reflectance field instrument"
Wendy Rosenblum, 1990, "Optimal selection of textural and spectral features for scene segmentation"
Eric Shor, 1990, "Longwave infrared synthetic scene simulation"
James Warnick, 1990, "A quantitative analysis of a self-emitting thermal IR scene simulation system"
Curtis Munechika, 1990, "Merging panchromatic and multispectral images for enhanced image analysis" U.S. Air Force
Xiaofan Feng, 1990, "Comparison of methods for generation of absolute reflectance factor measurements for BRDF studies"
Rolando Raqueño, 1990, "Automated boundary detection of echocardiograms" (M.S. Computer Science)
Wendy Rosenblum, May 1990, “Optimal selection of textural and spectral features for scene segmentation”
Eric Shor, May 1990, “3-D longwave infrared synthetic scene simulation”
Jonathan Wright, 1991, "Evaluation of LOWTRAN and MOTRAN for use over high zenith angle/long path length viewing" U.S. Air Force
Craig Eubanks, 1991, "Comparison of ellipso-polarimetry and dark field methods for determining of thickness variations in thin films"
Marc Lapointe, 1991, “Substitution of the Statistical Range for the Variance in Two Local Noise Smoothing Algorithms” Canadian Forces
Robert Mericsko, 1992, "Enhancements to atmospheric correction techniques for multiple thermal images"
Gustav Braun, 1992, "Quantitative evaluation of six multi-spectral, multi-resolution image merger routines"
Sharon Cady, 1992, "Multi-scene atmospheric normalization of airborne imagery: application to the remote measurement of lake acidification"
David Ehrhard, 1992, "Application of Fourier-based features for classification of synthetic aperture radar imagery" U.S. Air Force
Bernard Brower, 1992, "Evaluation of digital image compression algorithms for use on lap top computers"

Sharon Cady, April 1992, “Multi-scene atmospheric normalization of airborne imagery: Application to the remote measurement of lake acidification”

Robert Merisko, 1992, “Enhancement to atmospheric-correction techniques for multiple thermal images”

Donna Rankin, 1992, "Validation of DIRSIG an infrared synthetic scene generation model"

Adam Hanson, 1993, “Character recognition of optically blurred textual images using moment invariants”

Craig Laben, 1993, "A comparison of methods for forming multitemporal composites from NOAA advanced very high resolution radiometer data"

Kaleen Moriarty, 1993, “Automated image-to-image rectification for use in change detection analysis as applied to forest clearcut mapping”

Tom Servoss, 1993, "Infrared symbolic scene comparator"

Richard Stark, 1993, "Synthetic image generator model: application of specular and diffuse reflectivity components and performance evaluation in the visible region" U.S. Air Force

Eleni Paliouras, 1994, "Characterization of spatial texture for use in segmentation of synthetic aperture radar imagery"

Robert Rose, 1994, "The generation and comparison of multispectral synthetic textures"

Joseph Sirianni, 1994, "Heat transfer in DIRSIG an infrared synthetic scene generation model"

Gary Ralph, 1994, "Characterization of the radiometric performance of an IR scene projector" Canadian Forces

Serge Dutremble, 1995, "Temporal sampling of forward looking infrared imagery for subresolution enhancement post processing" Canadian Forces

Elizabeth Frey, 1995, “An examination of distributional assumptions in Landsat TM imagery”

Steven Nessmiller, 1995, "A comparison of the performance of non-parametric classifiers with Gaussian maximum likelihood for the classification of multispectral remotely sensed data" U.S. Air Force

Jim Salicain, 1995, "Simulation of camera model sensor geometry effects"

Alexander J. Granica, 1996, "Modeling of the radiometric characteristics of a simulated flourescent imager"

Todd A. Kraska, 1996, "Digital Imaging and Remote Sensing Image Generation Model: infrared airborne validation & input parameter analysis" U.S. Air Force

Frank J. Tantalo, 1996, "Modeling the MTF and noise characteristics of an image chain for a synthetic image generation system"

Russell A. White, 1996, "Validation of Rochester Institute of Technology’s (RIT’s) Digital Image and Remote Sensing Image Generation (DIRSIG) model-reflective region" U.S. Air Force

Jeffrey Allen, 1997, "Methods of digital classification accuracy assessment"

Paul Llewellyn Barnes, 1997, "In-scene atmospheric correction for multispectral imagery"

Todd Birdsall, 1997, "The development of an analytical model for the Kodak digital science color infrared cameras and its aerial imaging applications"

Phil Edwards, 1997, "A Canadian Resource Guide for a Water Quality Study of Lake Ontario" Canadian Forces

Gary Robinson, 1997, "Evaluation of two applications of spectral mixing models to image fusion" U.S. Air Force

David Schlingmeier, 1997, "Resolution enhancement of thermal infrared images via high resolution class-map and statistical methods" Canadian Forces

Tom Haake, 1998, "Modeling Topography Effects with DIRSIG

David Joseph, 1998, "DIRSIG: A broadband validation and evaluation of potential for infrared imaging spectroscopy"

Julia Laurenzano, 1998, "A comparative analysis of spectral band selection techniques" U.S. Air Force

Francois Alain, 1999, “Simulation of Imaging Fourier Transform Spectrometers Using DIRSIG” Canadian Forces

Dilkushi Anuja de Alwis, 1999, “Simulation of the formation and propagation of the thermal bar on Lake Ontario”

Daisei Konno, 1999, “Development and Testing of Improved Spectral Unmixing Techniques”

Emmett Ientilucci, 1999, “Synthetic simulation and modeling of image intensified CCDs (IICCD)”

Pete Arnold, 2000, “Modeling and Simulating Chemical Weapon Dispersal Patterns in DIRSIG”

Julia Barsi, 2000, “MISI and Landsat ETM+ : thermal calibration and atmospheric correction”

Robert Gray, 2000, “Modeling Forests for Synthetic Image Generation” Computer Science

Mary Ellen Miller, 2000, "An approach for assessment of Great Lakes Water Quality using Remote Sensing”

Nikole Wilson, 2000, "Hyperspectral Imaging for Bottom Type Classification and Water Depth Determination"

Kirk Knobelspiesse, 2000, "Atmospheric Compensation for SeaWiFS Images of Lake Superior"

John Klatt, 2001, “Error Characterization of Spectral Products using a Factorial Designed Experiment” Canadian Forces

Andrew Fordham, 2002, “Band Selection and Algorithm Development for Remote Sensing of Wildfires”

Neil Scanlan, 2003, “Comparative Performance Analysis of Texture Characterization Models in DIRSIG” Canadian Forces
Karl Walli, 2003, “Multisensor Image Registration Utilizing the LoG Filter and FWT”, US Air Force
Kris Barcomb, 2004, “High Resolution, Slant Angle Scene Generation and Validation of Concealed Targets in DIRSIG”, US Air Force
Gabriel Dore, 2004, “Multiframe Super-Resolution of Color Image Sequences Using a Global Motion Model”, Canadian Forces
Erin Peterson, 2004, “Synthetic Landmine Scene Development and Validation in DIRSIG”, US Air Force
Nancy Baccheschi, 2005, “Generation of a Combined Dataset of Simulated RADAR and Electro-Optical Imagery”, US Air Force
Noah Block, 2005, “A Sensitivity Study of a Polychromatic Sparse Aperture System”.
David Grimm, 2005, “Comparison of Hyperspectral Imagery Target Detection Algorithm Chains”, US Air Force.
Melissa Hofer (Computer Science), 2005, “A website and corresponding database to support the Digital Imaging and Remote Sensing (DIRS) lab in the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology”
Gretchen Sprehe, 2005, "Application of Phenology to Assist in Hyperspectral Species Classification in a Northern Hardwood Forest"
Jason West, 2005, “Matched Filter Stochastic Background Characterization for Hyperspectral Target Detection”, US Air Force
Pierre Chouinard, 2006, “Decision Fusion of Hyperspectral and Synthetic Aperture Radar Imagery for Trafficability Assessment”, Canadian Forces.
Brian Dobbs, 2006, “The incorporation of atmospheric variability into DIRSIG”
Kristin-Elke Strackerjan, 2006, Modeling the Spectral Effects of Water and Soil as Surface Contaminants in a High Resolution Optical Image Simulation”, Canadian Forces
Adam Cisz, 2006, “Performance Comparison of Hyperspectral Target Detection Algorithms”.
Seth Weith-Glushko, 2007, “Quantitative analysis of infrared contrast enhancement algorithms”
Domenico Luisi, 2007, “Conceptual design and Specification of a MICROSATELLITE Forest fire Detection System” Canadian Forces.

B.S. Projects

Jeffrey Sefl, 1983, "Determination of the transformation relationship of pseudo-invariant features of two Landsat images"
Kirk Smedley, 1986, "Imaging land/water demarcation lines for coastal mapping"
David Sapone, 1988, "Verification of a thermal model through radiometric methods"
Joshua Colwell and Eric Higgins, 1988, "Determination of the modulation transfer function of a thermal infrared line scanner"
Donald Marsh, 1989, "Photometric processing and interpretation of ratioed imagery by multispectral discriminate analysis for separation of geologic types"
Fred Stellwagon, 1989, "Classification of mixed pixels"
Brian Jalet, 1991, "Evaluation of methods of cloud removal in multidate NOAA/AVHRR imaging and its application to vegetational growth monitoring"
Mike Heath, 1991, "Perspective scene generation employing real imagery"
Stephen Ranck, 1991, "Establishment of a simple geographic information system utilizing digital data"
James Schryver, 1991, "Topographical analysis of a raster geographic information system"
Robert Rose, 1992, "Design of the information dissemination technique for a heat loss study"
Joseph Sirianni, 1992, "Production of realistic-looking sky radiance in the SIG process"
Andy Martelli, 1992, "Color calibration of an Agfa matrix QCR camera for Ektar 100 and 125 color print films"
Mike Branciforte, 1993, "An automated video tracking unit based on a matched filter segmentation algorithm"
Brian Heath, 1993, "Use of a quad cell in tracking a unit"
Debbie Wexler, 1993, "Texture generation using a stochastic model"
Michael Platt, 1994, "Evaluation of the feasibility of using digital terrain elevation models for the generation of multispectral images at Landsat resolution"
Cory Mau, 1994, "Incorporation of wind effects in IR scene simulation"

Paul Barnes, 1995, "Introduction of vegetation canopy models into DIRSIG"
Jeff Ducharme, 1995, "Atmospheric downwelled radiance"
Chip Garnier, 1995, "Integrating sphere calibration"
Jeff Allen, 1996, "Comparison of modeled and real vegetation imagery"
Emmett Ientilucci, 1996, "Blackbody calibration of MISI"
Charles Farnung, 1997, "DIRSIG camouflage phenomenology"
Peter Arnold, 1997, "BRDF approximation using a mathematical cone function"
Julia Barsi, 1997, "The generation of a GIS database in support of Great Lakes Studies"
Jason Calus, 1997, "Modeling of focal plane geometry in DIRSIG"
Arnold Hunt, 1997, "Validation of BRDF model in DIRSIG"
Michael C. Baglivio, 1998, "Error Characterization of the Alpha Residuals Emissivity Extraction Technique"
Brian Bleeze, 1998, "Modeling the MTF and Noise Characteristics of Complex Image Formation Systems"
Chia Chang, 1998, "Evaluation of Inversion Algorithms on DIRSIG Generated Plume Model Simulations"
Peter Kopacz, 1998, "Simulation of Geometric Distortions in Line Scanner Imagery"
Jason Hamel, 1999, "Simulation of Spectra Signatures of Chemical Leachates from Landfills"
Daniel Newland, 1999, "Evaluation of Stepwise Spectral Unmixing with HYDICE Data"
J. Meghan Salmon, 2000, "Derivative Spectroscopy for Remote Sensing of Water Quality"
Janel Schubbuck, 2000, "Thermal Calibration of MISI"
Matt Banta, 2001, "Lunar Calibration Techniques"
Christy Burtner, 2001, "Texture Characterization in DIRSIG"
Adam Goodenough, 2001."Evaluating Water Quality Monitoring with Hyperspectral Imagery"
Robert Light, 2001, "Hamamatsu R5900-01-L16 Photomultiplier Tube Spectral / Spatial Characterization"
Erin O'Donnell, 2001, "Historical Radiometric Calibration of Landsat 5"
Nikolaus Schad, 2001, "Hyperspectral Classification with Atmospheric Correction"
Cindy Scigaj, 2001, "Design and Implementation of a LIDAR Imaging System"
Eric Sztanko, 2001. "Imaging Fourier Transform Spectrometer: Design, Construction, and Evaluation"
Eric Webber, 2001, "Sensitivity Analysis of Atmospheric Compensation Algorithms for Multispectral Systems Configuration"
Adam Cisz, 2002, "Multispectral Fire Detection: Thermal/IR, Potassium, and Visual"
Rose of Sharon Daly, 2002, "Polarimetric Imaging"
Matthew D. Egan, 2002, "Detection and Analysis of Industrial Gas Plumes"
Carolyn S. Kennedy, 2002, "The Testing and Assessment of Texturing Tools Used to Build Scenes in DIRSIG"
David Pogorzala, 2002, "Setting Fire to CIS, Small - Scale Combustion Chamber and Instrumentation"
Jonathan Antal, 2002, "Error Characterization of Hyperspectral Products with Emphasis on Atmospheric Correction Techniques"
Kenneth R. Ewald, 2002, "Creation of ISO Target 16067-1"
Jared Clock, 2003, "Inexpensive Color Infrared Camera"
Gary Hoffmann, 2003, "Visual Enhancement of the Archimedes Palimpsest Using a Target Detection Algorithm"
Jill Marcin, 2003, "Effects of Contamination on Spectral Signatures"
Brandon Migdal, 2004, "Watermark Extraction Methods for Linearly Distorted Images to Maximize Signal-to-Noise Ratio"
Alvin Spivey, 2004, "An approach to synthetic scene completion and periodic noise removal by image inpainting and resynthesis"
Seth Weith-Glushko, 2004, "Automatic Tie-Point Generation for Oblique Aerial Imagery: An Algorithm"
Rachael Gold, 2005 "Performance Analysis of the Invariant Algorithm for Target Detection in Hyperspectral Imagery"
Michael Muldowney, 2005, "Time Series Analysis of Late Summer Microcystis Algae Blooms through Remote Sensing"
Brian Staab, 2005, "Investigation of Noise and Dimensionality Reduction Transforms on Hyperspectral Data as Applied to Target Detection"
Christopher Bayer, 2005, "Development of algorithm for fusion of hyperspectral and multispectral imagery with the objective of improving spatial resolution while retaining spectral data"
Michael Denning, 2007, "Classification of astronomical infrared sources using Spitzer space telescope data"
Justin Kwong, 2007, "Impact of calibration errors on physics based target detection"
Sarah Paul, 2007, "Investigation of VisiBall glasses claims"

7.0 Special Events

7.1 DIRS Annual Research Symposium

The DIRS Annual Research Symposium was held on June 5, 2007. It was another well attended event providing an opportunity to share results with our corporate and government sponsors. Topics covered in this year's event are outlined as follows:

- Semi-automated Scene Building – Stephen Lach (Ph.D. Student)
- Synthetic Modeling using Photonic Mapping – Adam Goodenough (Ph.D. Student)
- Mechanical Draft Cooling Tower Modeling – Matthew Montanaro (Ph.D. Student)
- Polarimetric Imaging Systems: analysis and modeling – David Messinger (Research Faculty)
- DIRSIG: Current State of Development – Scott Brown (Research Staff)
- Physics-based Algorithm Development Status – Emmett Ientilucci (Research Staff)
- Geometric Modeling and Processing of MISI HSI Data – Jason Casey (M.S. Student)
- Fusion of LIDAR and HSI Data for Target Detection – Michael Foster (Ph.D. Student)
- Water Quality Prediction using MODIS and ALGE – Anthony Vodacek (Faculty)
- Airborne Imaging Applications – Don McKeown (Research Staff)

We also had opportunity to discuss research priorities and received excellent feedback from our partners.