RIT | Chester F. Carlson Center for Imaging Science
Digital Imaging and Remote Sensing Laboratory

Annual Report 2023-2024

Cover Photo

The Suburban Scene is one project that the DIRSIG team has been working on in an effort to significantly progress their research and development of procedural scene development tools. The Suburban Scene uses vector based road networks to define and generate cells where we can use 3D assets to procedural generate subruban scenes at a rapid pace. [Photo credit: DIRSIG Scene Building Team].

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Foreword

Carl Salvaggio

Foreword

The 2023-2024 fiscal year has come to a close, and all the members of the Digital Imaging and Remote Sensing (DIRS) laboratory have had another wonderful, successful, and productive year. Building on our traditional expertise in the physics-based and statistical approaches to multispectral, hyperspectral, thermal, LiDAR, and synthetic aperture radar imagery collection, formation, exploitation, and scene modeling, we continue to embrace and build on the powers of data science to enhance our prolific contributions to the field of remote-sensing-related basic and applied research.

All of us in the DIRS laboratory continue to value our educational mission above all else, with everyone in our group contributing in their own multi-faceted fashion. Traditional classroom education in imaging science, specialized electives in remote sensing science including new coursework in synthetic aperture radar offered this year, mentorship of our graduate and undergraduate students in their many and varied research areas applying imaging science to remote-sensing problems, and the development of world-class imagery collection and synthetic scene simulation capabilities allow our students to do things that students in no other academic program can do globally. We reported three years ago that Emmett Ientilucci was the recipient of the 2020-2021 Richard and Virginia Eisenhart Provost's Award for Excellence in Teaching. Two years ago, we reported that Jan van Aardt was the recipient of the 2021-2022 Eisenhart Award for Outstanding Teaching. This year, I was humbled to be named as the recipient of the 2023-2024 Eisenhart Award for Outstanding Teaching. I could not be more proud of what it says that three of the Imaging Science faculty, who are members of the DIRS laboratory, have been honored with RIT's highest honor for teaching - I don't think there are many academic research laboratories that can report such a strong commitment to educational excellence.

We are seeing "shifts in the winds" of the remote-sensing industry with the proliferation of a large number of commercial satellites coming online, across all modalities, and the usage of the large amount of data that these systems are, and will be providing, will diversify the approaches that we pursue to solve problems. This came quickly, has affected some of our traditional and long-standing programs, but we have all pulled together and are planning our future directions.

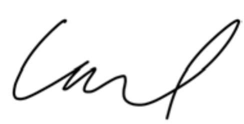
This year, we bid a fond farewell to Colleen McMahon, our research program coordinator, who has pursued a new opportunity within RIT. Anyone who has been a part of our laboratory, or has had the opportunity to work with Colleen around the University, knows her contributions have been invaluable. While we are sad to see her go, we are proud of the leadership and expertise our alumni continue to offer beyond our laboratory.

As I always say, and truly mean, I am so grateful for the support we get each year from the many organizations that are needed to run a research laboratory on a university campus. Here at RIT, I want to thank the many individuals that help us every day, and forgive me if I miss any individual as there are so many. Denis Charlesworth and Susan Michel from Sponsored Research Services (SRS) provide so much guidance day-to-day to help us from project beginning to end, Laura Girolamo and Amanda Zeluff from the Controller's Office and Sponsored Program Accounting keep us on the straight and narrow and provide all the guidance to keep our many projects compliant with contract requirements, our partners in the Human Resources Office for the countless hours they spend with me to make the DIRS laboratory a place that supports the needs of all its members. All of these folks are so important to us in making this laboratory a place where we can all function to the best of our abilities.

A special thank you to Jan van Aardt, our new Center Director, and André Hudson, Dean of the College of Science, for their unwavering support. We are also thankful for the strategic alignment and support from Ryne Raffaelle, Vice President for Research, and the top-level encouragement and support from President David Munson and Provost Prabu David. For those of you who read these reports annually, you will notice several new faces in our administration this year, and we are thrilled to have the continued support that we have always enjoyed during our four-decade presence at RIT. Thanks to all for giving us such a great academic environment in which to thrive.

If you were "listening" carefully in the previous statement, you heard correctly, the DIRS laboratory is now 40 years old. I can only follow that statement by saying... Wow!!! We are all very proud to be part of such a long-standing enterprise and tradition, some of us here from the very beginning. Stay tuned for upcoming special events as we celebrate this milestone. We are excited to uphold and advance our legacy of excellence in the coming years.

My warmest regards,



Carl Salvaggio

Performance

FY24 DIRS Laboratory Sponsored Research by the Numbers

31
Proposal Submitted

$23M
Proposal Submitted Value

$3.9M
Obligated Sponsor Research

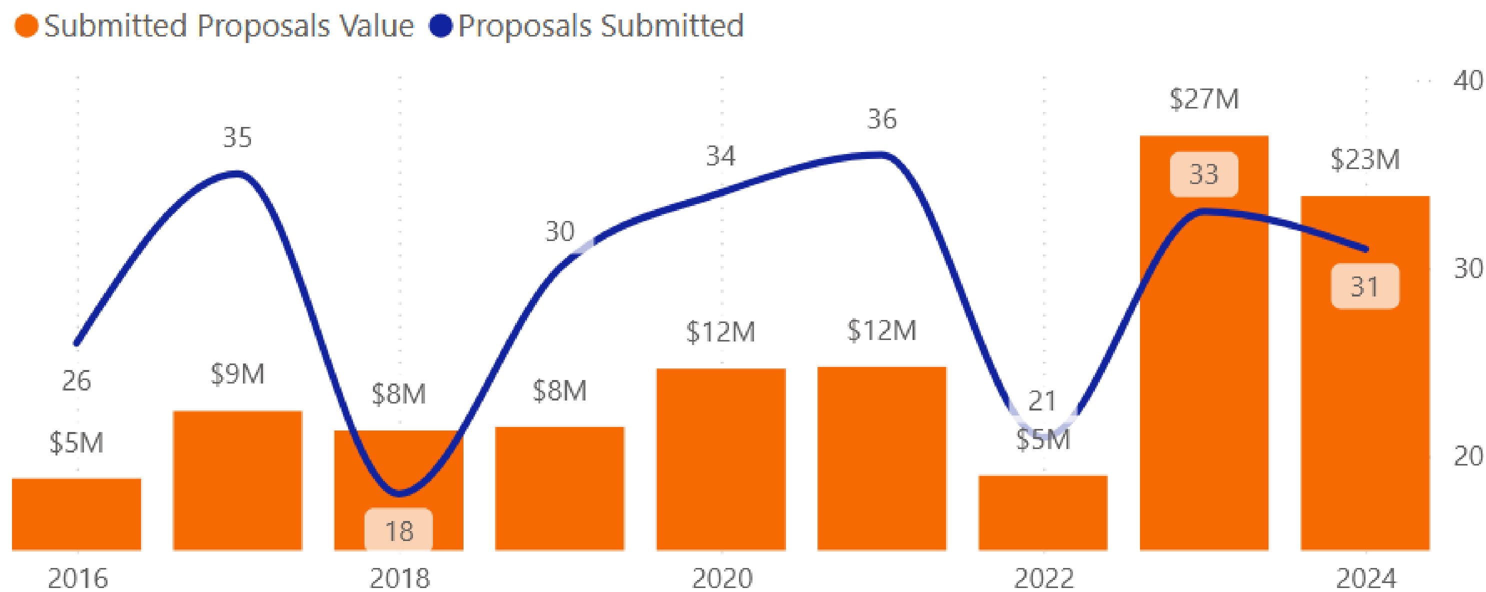
$1.5M
New Funded Sponsored Research (7)

66%
Of Center for Imaging Science
Total Obligated Dollars

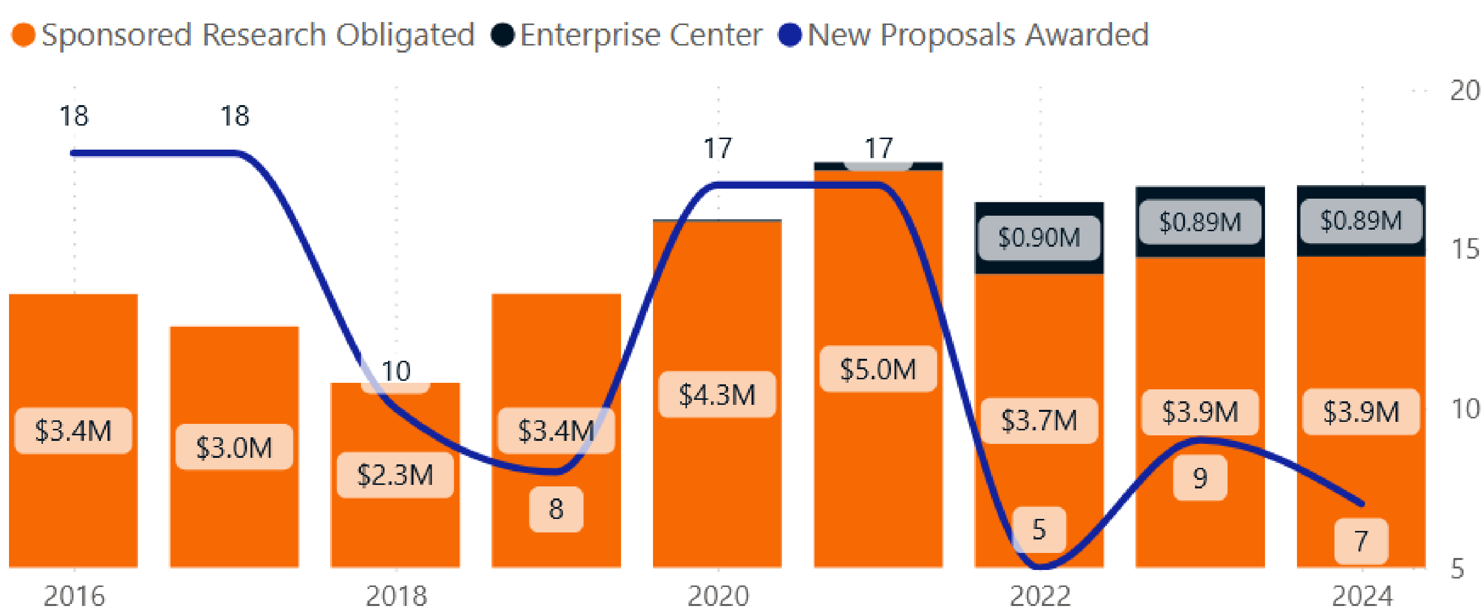
25%
Of College of Science
Total Obligated Dollars

$98K
Masters Tuition supported
through Sponsored Research

$260K
Ph.D. Tuition supported
through Sponsored Research



Sponsored research proposal activity by fiscal year for the principal investigators associated with the Digital Imaging and Remote Sensing Laboratory.



Sponsored research obligated funds, Enterprise Center total invoiced, and new proposals awarded by fiscal year for the Digital Imaging and remote Sensing Laboratory

Digital Imaging and Remote Sensing Laboratory Enterprise Center

The DIRS laboratory, with deep expertise in drones, imaging and remote sensing technology has been offering its services to the public since late 2019. Through the Digital Imaging and Remote Sensing (DIRS) Enterprise Center (EC), customers can hire faculty and staff from our Lab to provide training, consulting, data collection, equipment calibration and more. The DIRS Enterprise Center is one of many RIT Enterprise Centers offering fee-for-service as a vendor.

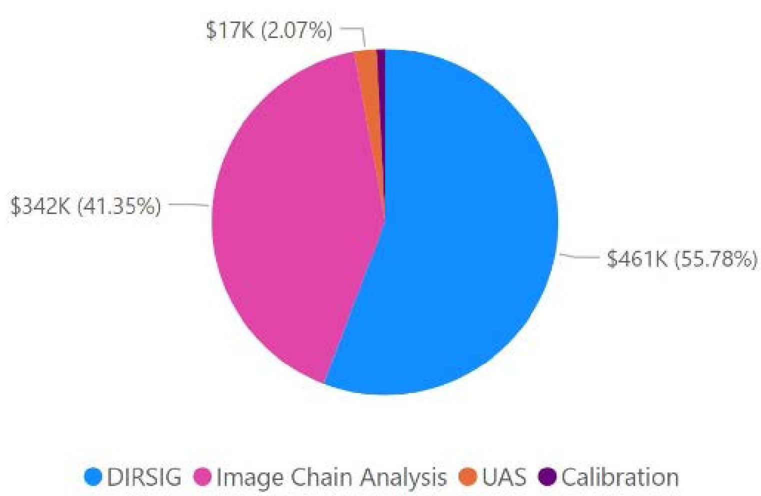
We are excited to work with new collaborators and expect to support a wide range of industries as we continue to provide high-quality data and services.

25
Quotes Submitted

19
Funded Projects

$1.4M
Quotes Submitted Value

$890K
Invoiced



Digital Imaging and Remote Sensing Laboratory + Enterprise Center FY24 Performance

$4.8M
Total Obligated Dollars

81%
Of Center for Imaging Science Total Obligated Dollars

31%
Of College of Science Total Obligated Dollars

11
Undergraduate Students Supported

42
Graduate Students Supported

34
Publications

16
PIs Submitting Proposals

Research

The following represents selected projects conducted by the students, research staff, and faculty of the Digital Imaging and Remote Sensing Laboratory during the 2022-2023 academic year. These projects are in various stages of their lifecycle and are representative of the widely varying interests and capabilities of our scientific researchers.

DIRSIG5 Development

Sponsor: Multiple
Principal Investigator: Scott Brown
Research Team: Adam Goodenough, Byron Eng, Grady Saunders, Jeff Dank, Serena Flint, Jacob Irizarry

Project Description

The DIRSIG team has been focused on supporting large area scenes, new capabilities, and quality of life improvements. These improvements were developed under various projects with both internal and external collaborators. The new features and improvements resulted the addition of over 11,000 words of new documentation.

Project Status

This year, the DIRSIG team tested the limits of scene construction by developing our largest scene yet. This scene represents a 40km x 40km area of alpine forest, complete with a mountain, foothills, rivers, and lowland areas. All terrain and terrain maps were generated using external tools and while inspired by Mt. Hood, Oregon, does not represent any real location on Earth. In total, there are 10 million tree instances scattered throughout the scene and 500,000 instances of ground foliage. The computational demand of procedurally generating millions of instances inspired some of the improvements to our scene construction methods described in the next paragraph.

Modeling single scenes that are larger than 10km in size can create precision issues (e.g. missing or displaced geometry) due to the single precision ray tracer (Intel's Embree) at DIRSIG 5's core. The solution to these precision issues has been to construct large scenes out of many individual tiles and to transition in and out of local scene coordinate spaces in order to mitigate precision errors. The current version of DIRISG 5 represents a concerted effort to facilitate and optimize that type of multi-scene construction and to ensure that the appropriate precision handling is being used for a wider range of simulations. These improvements have been concurrent with advances in DIRSIG's Space Domain Awareness (SDA) modeling capabilities to make sure that there are seamless transitions from 100s of kilometers down to centimeter or millimeter-scale geometry.

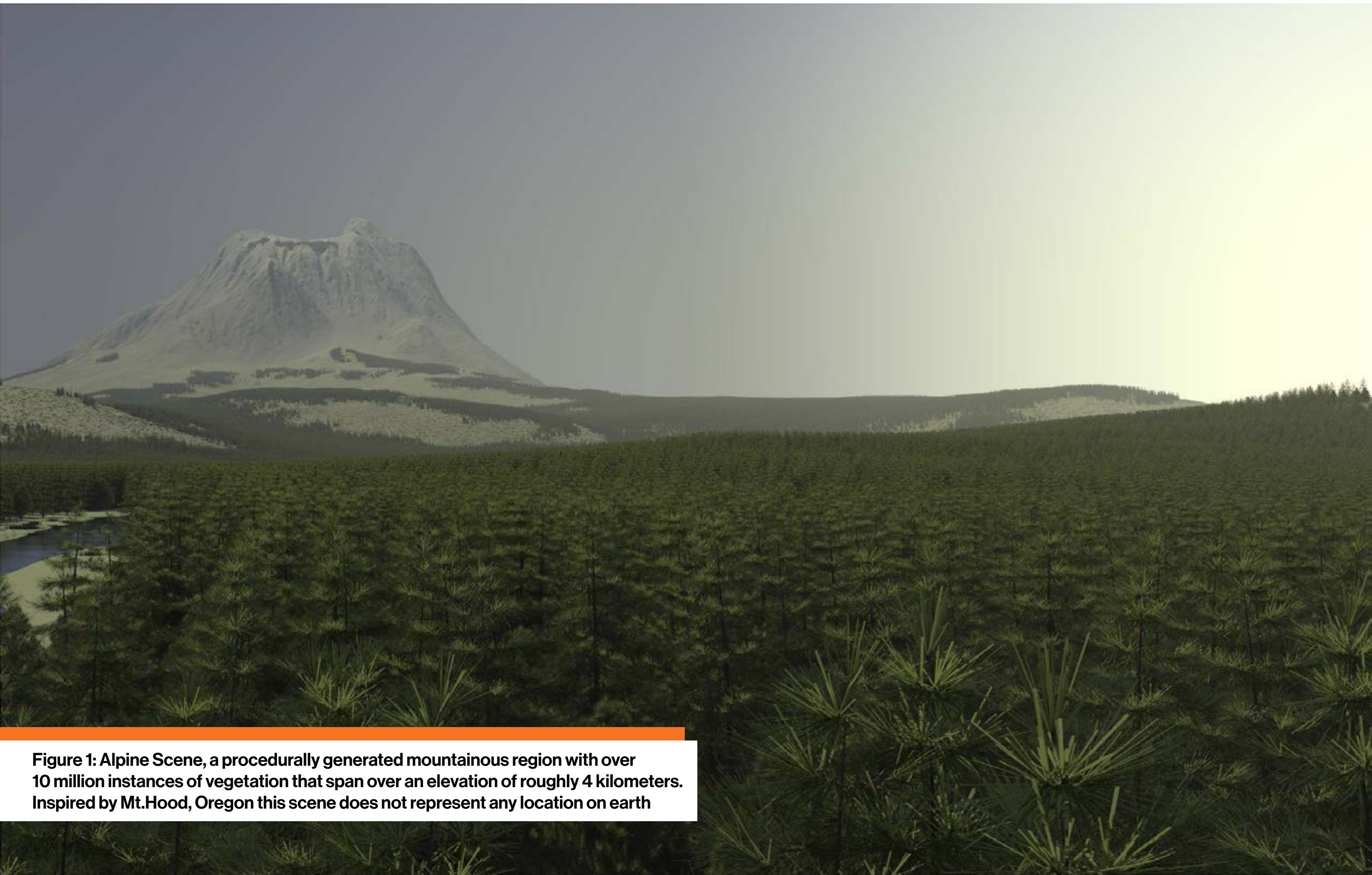


Figure 1: Alpine Scene, a procedurally generated mountainous region with over 10 million instances of vegetation that span over an elevation of roughly 4 kilometers. Inspired by Mt.Hood, Oregon this scene does not represent any location on earth

Figure 2: Desert Highway Scene, procedural foliage generation.

Figure 3: Topdown Imagery of procedurally generated suburban scene

In an effort to improve the level of geometric detail possible within large-scale DIRSIG scenes, significant progress was made in our research and development of procedural scene development tools. These tools focus on the systematic placement of objects including plants, buildings, and vehicles, in a structured yet randomized manner that adheres to logical constraints such as minimum object-to-object distances. As a result, a large-scale urban scene was successfully generated, complete with procedural road networks, alongside an updated version of the DesertHighway scene covering a much greater land area and featuring more instances of plants, shrubs, and other vegetation than any prior DIRSIG scene. A key milestone was the development of a new binary file format designed specifically for storing instances of scene objects. This drastically reduces the storage space required for millions of unique object placements, otherwise spelled out in XML, and enables significantly faster loading times in the DIRSIG scene compiler. Moreover, the format is straightforward to read and write with various programming and scripting languages, such as Python.

New plugins were introduced to DIRSIG5 for modeling plumes (e.g. a gaseous effluent release) and clouds. The cloud model has pre-calculated scattering phase functions and other spectral properties appropriate for common water droplet distributions in cumulous clouds and the plume model allows for fully user-defined properties, including the mixing of multiple materials in a plume. Both plugins are based on the OpenVDB voxel standard and new tools and examples have been provided, including how to setup dynamic inputs. A set of volume-specific truth products are also available to verify and understand output imagery.

A few quality-of-life improvements were added to DIRSIG this year. The most notable among these improvements is our new image viewer program. This new image viewer added many more features and options to the basic functions available in the old image viewer including scaling options, tone mapping, viewing and saving point data from radiance images and truth images simultaneously, and much more. A new feature was introduced to the NewAtmosphere plugin that allows users to configure MODTRAN atmospheres from a set of parameters. This drastically simplifies setup of the atmosphere without sacrificing customizability. Support for this feature was also added to the NewAtmosphere editor in DIRSIG's graphical user interface (GUI). Additionally, users can now configure DIRSIG5's ThermWeather and NsrdbWeather plugins directly from the GUI.

By default, DIRSIG's main sensor plugin, BasicPlatform, casts out rays for path tracing from a pinhole location. This pinhole approximation causes an infinite focus where everything in the scene, no matter how far away from the sensor, is in crisp focus. A new feature was added to BasicPlatform that allows the user to model non-infinite depth of focus. This is accomplished by providing an aperture size and focus distance, causing foreground and background blurring due to the path origins coming from the aperture disc rather than a pinhole location.

A new LightCurve plugin was created to support SDA applications within DIRSIG. This plugin collects data from a single target over a period of time and outputs a time series of the data. This allows users to produce light curves without the need to run multiple frames of full framing array simulations and extracting time series data from the output. The LightCurve plugin makes the simulation setup easier and produces the data much faster than previous methods.

Exploiting Subpixel Scattering Mechanisms to Identify Unresolved Targets in SAR Data

Principal Investigator: James Albano

Project Description

While many commercial SAR satellite systems can achieve resolutions as fine as 0.5 m, finer resolution is required to identify ground vehicles in imagery. As an industry rule-of-thumb, 0.25 m is the coarsest resolution imagery one can pass to an automatic target recognition (ATR) system to obtain adequate detection probabilities. This project seeks to break this commonly used guideline by exploiting subpixel scattering mechanisms identified in the spatial frequency domain. Processing data in this domain is challenging because an object's energy is spread over the entire domain.

To address this challenge, the Adaptive Subpixel Target Recognition (ASTR) algorithm was developed. Figure 1 provides an overview. Digital Spotlighting is used first to reduce the clutter environment outside the area-of-interest. Xpatch is used to generate the target response vector for each target class of interest. This vector captures the subpixel scattering mechanisms that characterize each target class. The remaining clutter is characterized by the clutter covariance matrix and is used by the Adaptive Cosine Estimator (ACE) to make a statistical comparison between a target response vector and the phase history chip under test.

Project Status

Figure 2 shows an initial result of the algorithm. First, a target class is generated by randomly distributing twenty scattering centers with equal magnitude RCS within a single SAR resolution cell (i.e., a subpixel target). A set of confusers are generated using the same twenty scattering centers but with different spatial distributions compared to the target. The ACE score is near unity when presented a phase history chip containing the subpixel target while lower scores are obtained for each confuser. Further testing of the Adaptive Subpixel Target Recognition (ASTR) algorithm will be conducted over the next year. This includes a planned data collection with a commercial SAR vendor. Sandia National Laboratories provided funding for this project.

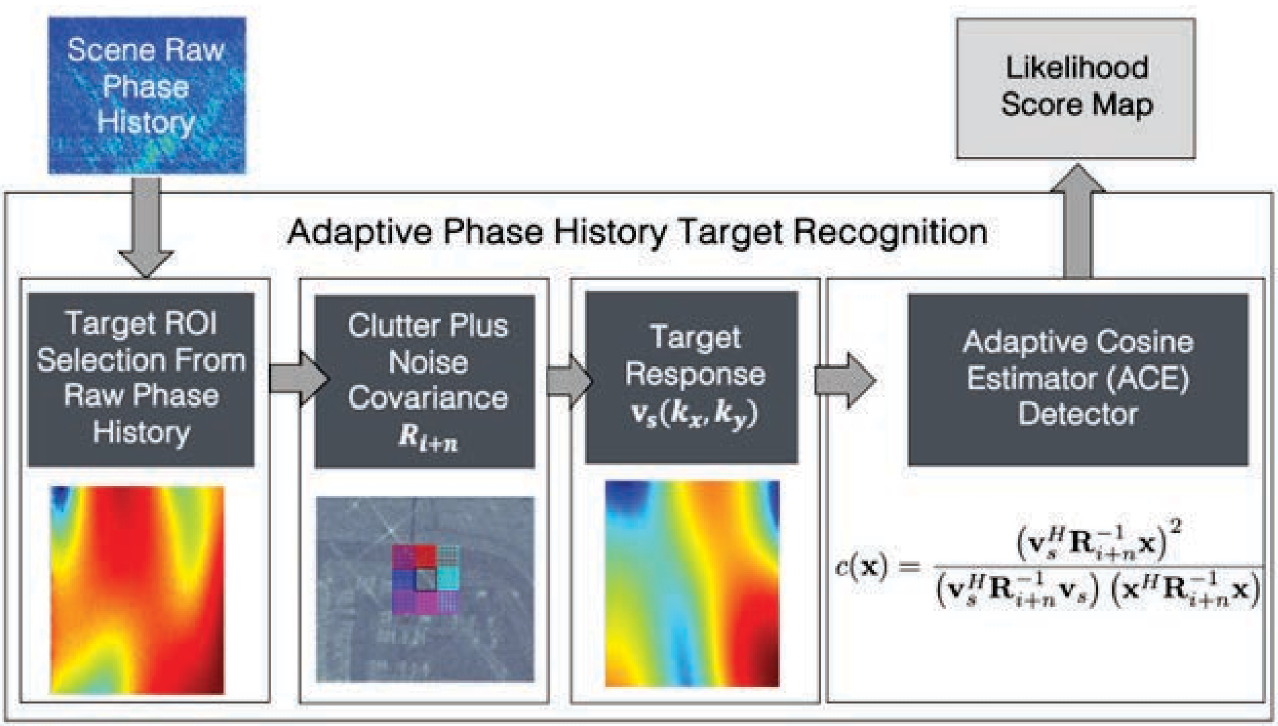


Figure 1: Signal processing workflow for the Adaptive Phase History Target Recognition algorithm.

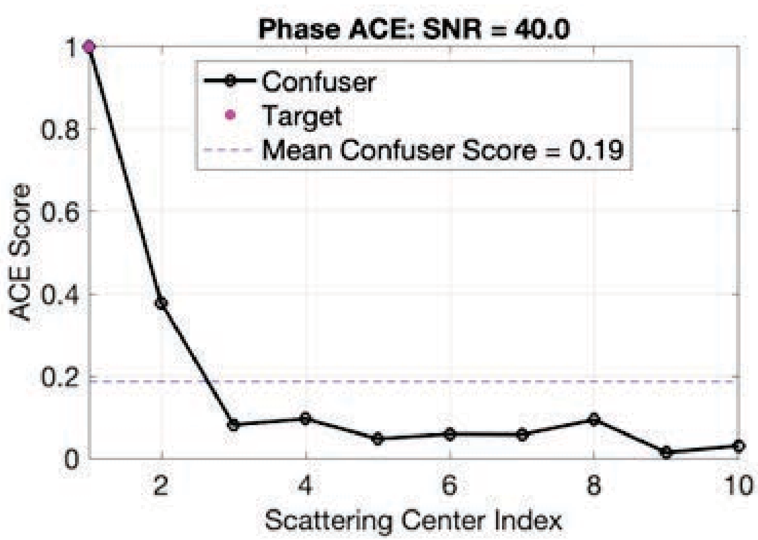


Figure 2: Initial results of the Adaptive Subpixel Target Recognition Algorithm.

Simulation and Modeling to Support Improved Landsat Next Science

Sponsor: NASA Goddard Space Flight Center

Principal Investigator: Aaron Gerace

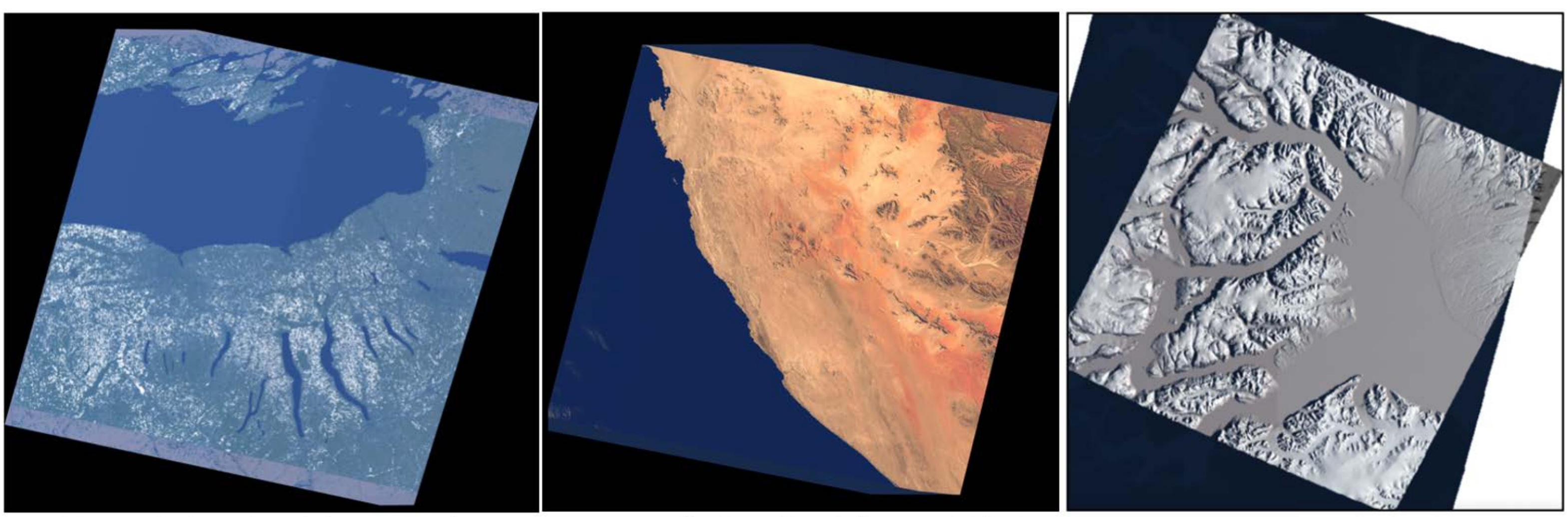
Research Staff: Rehman Eon, Matthew Montanaro, Amirhossein Hassanzadeh, Adam Goodenough, Timothy Bauch, Serena Flint

Project Description

The purpose of this three-year research project is to conduct simulation and modeling studies to help inform requirements for the next Landsat Earth-observation system, i.e., The Landsat Instrument Suite (LandIS). The next Landsat will be a significant deviation from past sensors as it will be comprised of three identical instruments, each containing twenty-six spectral bands, placed on separate observatories to address deficiencies in the Landsat data archive that were identified by science users; the next Landsat will have improved temporal, spectral, and spatial resolution. A consequence of these required improvements to LandIS will be a significant increase in data volume. As such, Year 1 efforts focused on the development of LandIS proxy data to assess compression routines designed to reduce the data volume while maintaining science quality data. Note that the proxy datasets (see Figure 1) use a workflow that enables spectral simulations so all twenty-six LandIS bands can be rendered.

Project Status

The LandIS instrument vendor has recently been announced so generic sensor models that were developed in Year 1 will be replaced with the vendor's specific architecture. Proxy data will be simulated with the updated sensor model to support ongoing compression studies and to support the assessment of other relevant requirements as the instrument is designed and fabricated.



RGB Rendering of Path/Row: 016/030 **RGB Rendering of Path/Row: 178/079** **RGB Rendering of Path/Row: 228/010**

Figure 1: Simulated LandIS (Bands 3, 4, & 8) 10m RGB proxy data for three World Reference System 2 (WRS-2) path/rows. Note that these data have a swath width of approximately 185km.

Fundamental Research on Detection and Classification Limits in Spectral Imagery

Sponsor: National Geospatial-Intelligence Agency

Principal Investigator: John Kerekes

Research Team: Chase Cañas, Colin Maloney, Scott Brown, Emmett Ientilucci

Project Description

With support from an NGA University Research Initiative award RIT continued to conduct research to understand the fundamental limits of multi- and hyperspectral imagery for the detection of surface objects and land cover classification. For over 50 years, spectral imagery from aircraft and satellites have been used in these applications and have demonstrated high levels of performance. But as technology and imaging system performance capabilities improve, a fundamental question remains: what are the physical limits in the use of passive remote optical observations to detect objects and classify surface areas? This project is pursuing answers to that question through the use of a previously developed analytical spectral imaging performance prediction tool.

Project Status

Initiated in July 2021 the project has completed its third year. Work has continued on recoding an original analytical model in C++ and compatible with RIT's physics-based simulation code DIRSIG. This tool is being used to explore limits of detection with hyperspectral imagery as a function of scene and sensor parameters. An automated framework has been developed by PhD student Chase Cañas and has been used in a demonstration to define surfaces in multidimensional space of system parameters for a given level of detection performance. The project is expected to conclude in the summer of 2025 with contributions to fundamental theory of limits on detection with spectral imagery as well as a software tool to explore such limits.

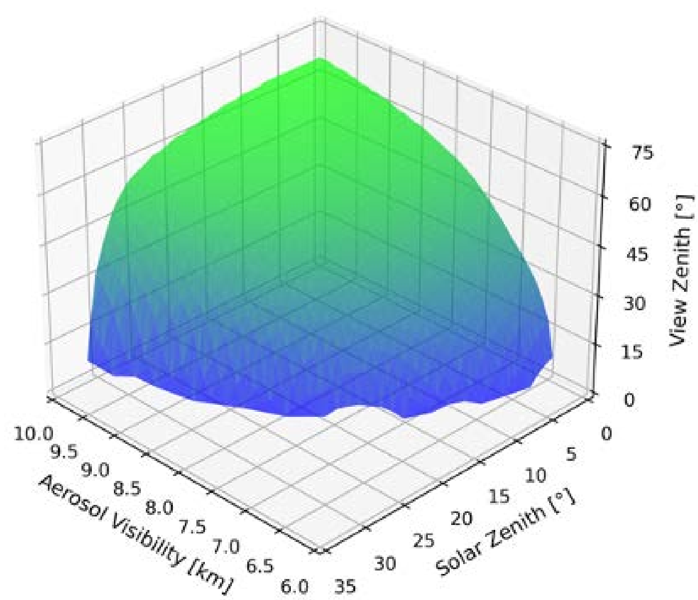


Figure 1. Visualization of surface delineating a limit on detection performance for an example situation of detecting a subpixel target with a hyperspectral imager. The surface shows a boundary for which the area under a receiver operating characteristic curve (AUC) is greater than a threshold. The volume under the surface contains combinations of scene and view parameters that allow a high detection rate (AUC > 0.94) for the scenario examined.

The Science of Non-resolved Space Object Signatures for Space Domain Awareness

Sponsor: Department of Air Force

Principal Investigator: Dr. Michael Gartley

Research Staff: Dr. Adam Goodenough, Dr. Scott Brown, Jacob Irizarry

External Collaborators: University of Texas – El Paso (UTEP), Georgia Tech Research Institute (GTRI), United States Air Force Academy (USAFA)

Project Description

This project is focused on leveraging modeling and simulation of non-resolved space object signatures utilizing the DIRSIG software model to better understand what the object is and what it might be doing. The non-resolved signatures are represented by time resolved light curves which are a function of the space object materials, surface orientations, illumination conditions, and viewing conditions. The DIRSIG software model is being used to generate spectral and polarimetric light curve training data for project collaborators to develop machine learning algorithms to characterize specific properties of unknown space objects. This characterization will ideally help identify the fundamental surfaces, shapes, and materials present on the unknown objects and ultimately aid the sponsor with a more thorough understanding of the object's purpose and operational status.

Project Status

During this project's first year, RIT worked on expanding capability within the DIRSIG5 software model to better support a wider variety of Space Domain Awareness (SDA) scenarios, performing spectral bidirectional reflectance distribution function (BRDF) measurements of satellite materials and subsequent incorporation into the DIRSIG simulations, verification of DIRSIG4 and DIRSIG5 for generation of light curves against measured data, and exploration of the impact of surface material roughness on light curve shape. Included in the improved DIRSIG5 support for SDA scenarios was the addition of a light curve plug-in that generates calibrated magnitude as a function of time without requiring a focal plane or platform description. Additionally, spectral BRDF measurements of space insulation materials were incorporated into DIRSIG simulations of geosynchronous satellites and compared to measurements collected by project partners at USAFA. RIT has found that the micro (BRDF) and macro-scale (geometric) roughness of space object surface materials has a significant impact on light curve shape and the resulting correlation with field measurements for known objects. Research is ongoing to develop an approach to estimate surface roughness and surface orientations by leveraging DIRSIG generated light curve signatures coupled with calibrated telescope light curve measurements. This understanding will ultimately lead towards improved characterization of unknown, non-resolved space object material type and shape.

RadSCape: radiative transfer simulation and validation of the dynamic structural and spectral properties of the vegetation of the Cape

Sponsors: NASA BioScape Program

Principal Investigator: Jan van Aardt

Team: Manisha Das Chaity, Ramesh Bhatta, Grady Saunders, Byron Eng, Jacob Irizzary, Dr. Jasper Slingsby (University of Cape Town, South Africa), Dr. Glenn Moncrieff (South African Ecological Observation Network)

Project Description

The Greater Cape Floristic Region (GCFR) in South Africa is a hyper-diverse region, compasses two global biodiversity hotspots, threatened by habitat loss and fragmentation, invasive species, altered fire regimes, and climate change. Managing and mitigating these threats requires regularly updated, spatially-explicit information for the entire region, which is currently only feasible using satellite remote sensing. However, detecting the signal change over the spectral and structural variability of ecosystems in the region is highly challenging due to the exceptionally high ecosystem diversity and the confounding influence of structural variables at the leaf, stem, and whole-crown scales. This complexity is exacerbated by the fact that GCFR contains spectacular plant diversity.

The objectives of this study are to build a simulated scene using a combination of fynbos trait measurements and radiative transfer modeling in a biophysically- and physics-robust simulation environment and then validate the scene with high spectral resolution and LiDAR remote sensing NASA data from the BioSCape project's aircraft campaigns. This will provide a mechanistic linking of structure/spectra-to-traits, and an ability to track biodiversity as a function of post-fire recovery. Achieving this goal could significantly improve our understanding of interactions of light within the fynbos biophysical traits and inform innovative uses of remote sensing data for highly diverse ecosystems at all scales, from airborne to satellite levels. Overall, this study presents a novel approach to resolving the challenge of simulating land surface reflectance spectra in a region with high ecosystem diversity, which could have important implications for the management and conservation of the GCFR.

Project Status

Our team focused on conducting extensive fieldwork in the second year of the BioSCape project to explore the diverse fynbos ecosystem in South Africa. We visited the Grootbos Private Nature Reserve in South Africa in October 2023 to collect field samples and drone data. We collected multispectral imagery for a subset of the total reserve area using a DJI Mavic 3 Multispectral drone, for six different burn years. In each of the burnt sites, we selected a sampling area near the center of the flight zone and estimated the percentage cover and the average height of each species that occurred within the plots to estimate species richness within each plot.

Spectral Biodiversity (Manisha Das Chaity): We exhaustively collected spectral measurements for various species at the leaf-level, for flowers, background, and invasive species in the range of 350-2500nm, using an Analytical Spectral Device (ASD; see Figure 1). We used the collected fieldwork data to ensure we covered the variation in fynbos structural and spectral traits. The fieldwork was supported by Dr. Jasper Slingsby (UCT), Dr. Glenn Moncrieff (SAEON), and Mr. Sean Privett (botanist; consultant), as well as the Grootbos Nature Reserve research personnel.

Building upon the success of Year 1, we have worked on refining our scene-building process in DIRSIG to enhance its accuracy and efficiency. This involved integrating advanced scene-building tools, making 3D objects of plant species, improving the PROSPECT model, and incorporating more sophisticated spectral data from our 2023 field trip. We also have incorporated the drone data to track changes in biodiversity and habitat conditions over the Fynbos region, to gain invaluable insights into ecosystem resilience and adaptation.

Figure 2 is an example of a simulated scene of the 2019 burn plot of fynbos in Grootbos private nature reserve. The integration of scene-building tools and comprehensive assets has greatly enhanced our ability to simulate the diverse ecosystem of fynbos within the DIRSIG framework. This virtual scene will also broaden our capacity to test the imaging instrument's effectiveness in capturing it.

Structural Biodiversity (Ramesh Bhatta): As an initial analysis we presented a method to characterize the low-stature shrubland ecosystem's structural differences using inexpensive structure-from-motion point cloud data obtained using drone aerial imagery collected as a part of our recent field campaign (October 2023). Four structural metrics, namely canopy height, top-rugosity, surface gap ratio, and surface point density, which represent multiple aspects of structure of vegetation, were proposed. We also showed that based on these metrices we can classify plots (5m x 5m) into their burn year (burn date) with a good accuracy. Our current work focuses on the utility analysis of mid-footprint size (6-8m) full waveform lidar (LVIS) for large scale structural-traits modelling of the low-stature shrublands. Along with that we plan to use DIRSIG simulation to generate synthetic waveform lidar data of various GCFR sites to identify potential challenges and optimize the lidar system parameters for detecting and differentiating low-lying features occurring in such low-stature environments.

A sample of lidar simulation of a scene using a drone based VLP16 lidar system is shown in Figure 3. We believe that such simulation-based methods can significantly improve the performance analysis of the sensor systems by providing a controlled and replicable framework for evaluating the system responses across multiple settings and this will lead us to specify the next generation systems capable of detangling structural variability of low-stature vegetation ecosystems.

Figure 1. Our team collected spectral data using an Analytical Spectral Device (ASD) field spectroradiometer in October 2023 in South Africa.

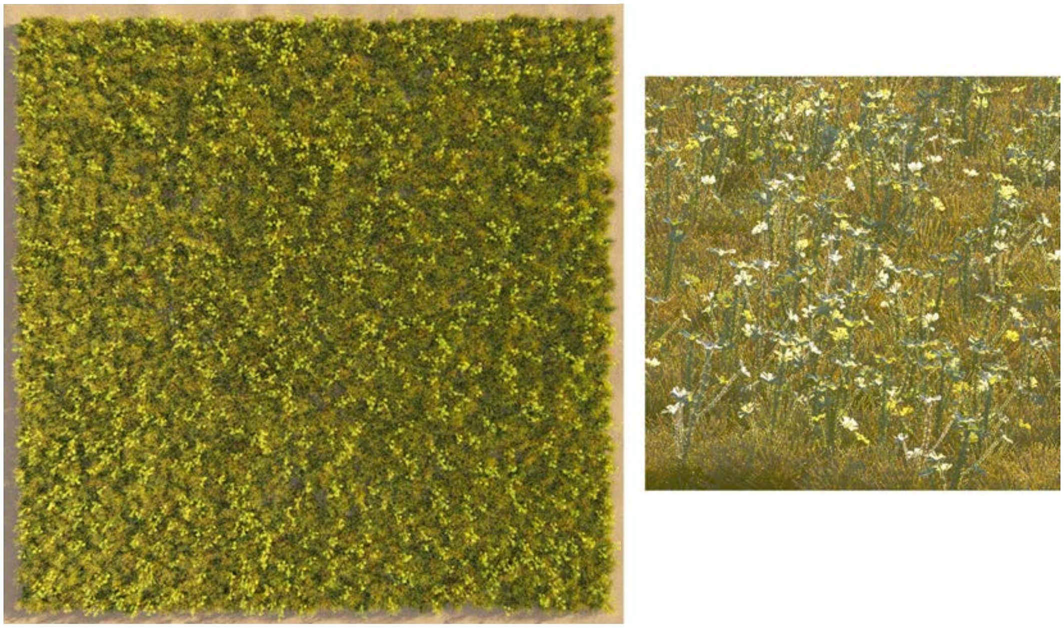


Figure 2. A rendering of the virtual scene of the fynbos developed by the DIRSIG simulator. The scene is captured using an RGB camera at 25 m altitude.

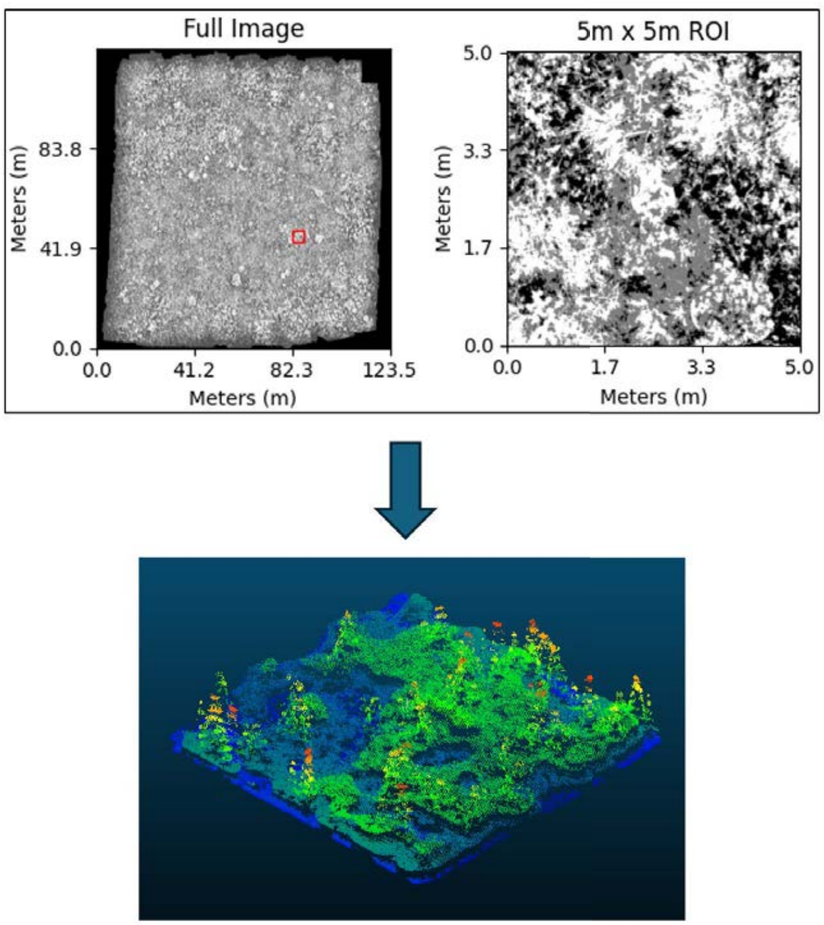


Figure 3: Simulation of fynbos burn year 2019 scene with drone based VLP16 Lidar system at 5m x 5m scale). Top shows selection of the ROI from full scene (red box) and bottom shows the simulated point cloud.

NSF Convergence Accelerator Track I: Accelerating Use of Geologically-driven Engineering and Reclamation (AUGER), A Predictive Approach to a Sustainable CriticalMinerals Industry

Sponsor: National Science Foundation (NSF)

Principal Investigator (Project Co-PI): Charles M. Bachmann

Research Staff: Chris Lee, Nayma Nur, Tim Bauch, Nina Raqueno, Brian Benner, Robert Chancia
External Collaborators: Karin Olson Hoal (Cornell University, PI); Louisa Smieska (Cornell University, Co-PI); Anthony Balladon (Phoenix Tailings, Co-PI); Jessica Stromberg (CSIRO, Co-PI); Greg Ray(Cornell University); Sriramya Duddukuri Nair (Cornell University)

Project Description

Major goals of this Phase 1 NSF Convergence Accelerator project included the development of a new and synergistic approach to mineral resource characterization linking multiple analysis tools and approaches for identifying critical mineral resources as well as repurposing of mine waste byproducts. Specifically, our team sought to link micro-scale tools normally confined to laboratory settings, such as high-fidelity x-ray fluorescence (XRF) measurements, with hyperspectral imaging (HSI) tools that can operate in both laboratory and field settings, building on the complimentary nature of these diagnostic tools for characterizing mineral resources. The project leveraged expertise in material characterization using XRF at the Cornell High Energy Synchrotron Source (CHESS) and RIT expertise within DIRS related to both drone hyperspectral imaging for environmental characterization as well as lab hyperspectral characterization of materials. Another related objective was to link the micro-scale analytical characterization to larger scales (site scale) where hyperspectral imaging technologies operating from remote sensing platforms (drones, fixed wing aircraft, and satellites) can be employed to analyze large areas. By engaging stakeholders during the execution of this project, our team goal was also to better understand and prioritize the specific material properties needed most by the mineral resource industry for identifying critical mineral resources as well as re-purposing waste byproducts such as mine tailings.

Project Status

In addition to technical work, team members interviewed stakeholders in the mineral resources industry as well as effected communities to determine the key parameters and analyses needed to develop a resource toolkit based on key technologies such as XRF and hyperspectral imaging. These interviews informed the technical goals that we pursued in experimental work in both field and laboratory settings over the course of this project. As part of this effort, our RIT team undertook an experiment at a former mine site in Mineville, NY, flying our drone-based imaging payloads to collect hyperspectral imagery, LiDAR, and thermal imagery. In additional, 3D site models were also constructed from orthorectified stereo RGB imagery, and our mast-based hyperspectral imaging system was also deployed to collect imagery, and extensive ground truth measurements were undertaken. Site samples were brought back from the experiment for laboratory analysis with our hyperspectral goniometer. We used this laboratory data, along with the imagery, to develop a novel workflow for extracting a key geophysical parameter, useful in the mineral resource industry, especially in decision-making associated with re-purposing mine waste.

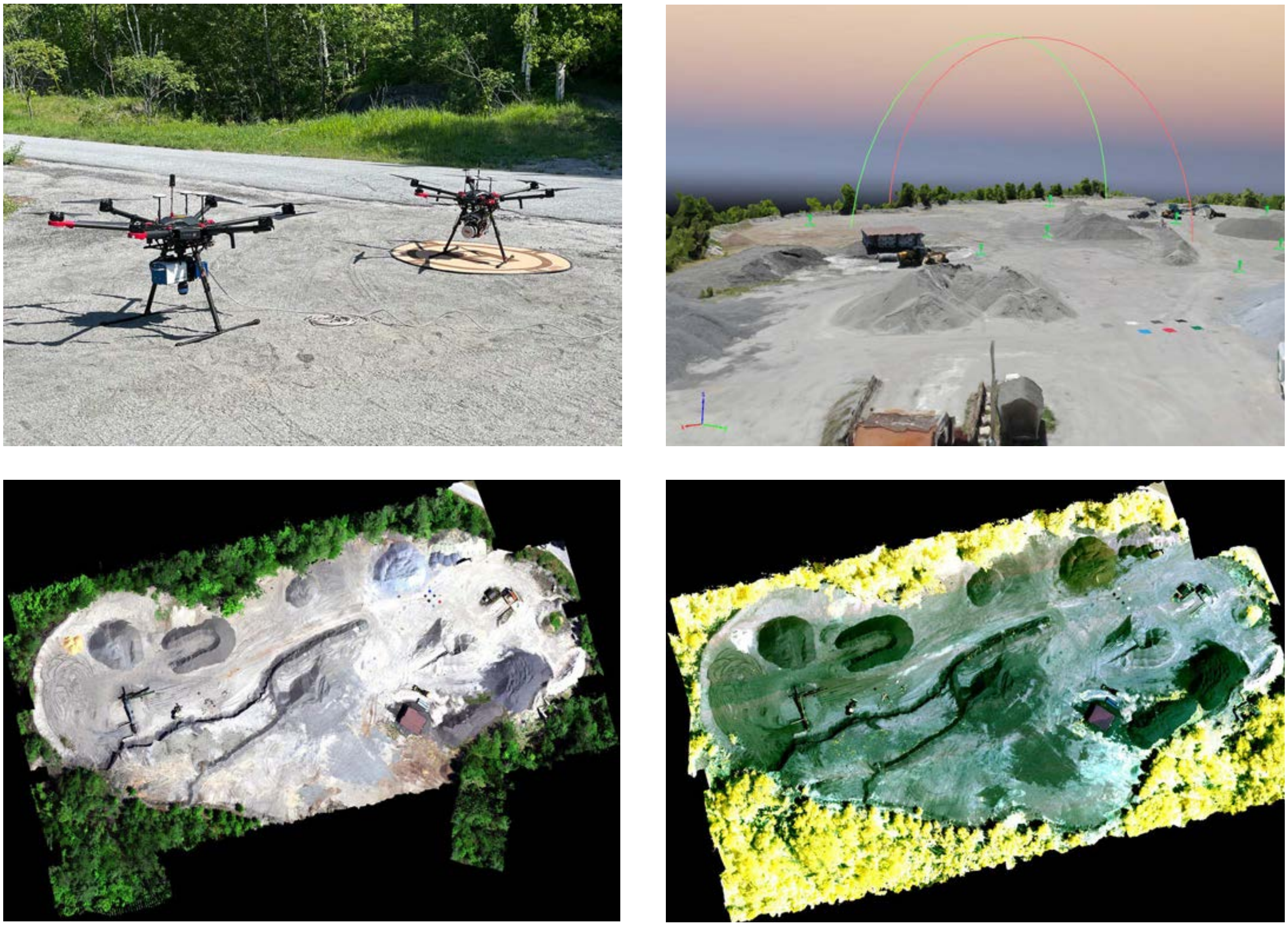


Figure 1: (Top, left) Two of the RIT drones during the remote sensing and field calibration and validation campaign at the mine site in Mineville, NY on May 30-31, 2023. (Top, right) 3D site model of the mine site constructed from stereo drone imagery. (Bottom row) Example drone hyperspectral imagery mosaics of the mine site: (bottom, left) hyperspectral VNIR mosaic, bands 28 (461.175 nm), 69 (550.224 nm), 109 (639.272 nm)); Hyperspectral SWIR mosaic, bands 10 (976.645 nm), 38 (1244.6801 nm), and 84 (1685.01 nm).

Enhanced 3D Sub-Canopy Mapping via Airborne/Spaceborne Full-Waveform LiDAR

Sponsors: National Geospatial-Intelligence Agency (NGA)

Principal Investigator: Jan van Aardt

Team: Robert Wible, Yuval Levental, Kedar Patki, Grady Saunders, and Dr. Keith Krause (Battelle), Amir Hassanzadeh

Project Description

The Digital Imaging and Remote Sensing Image Generation (DIRSIG) software can generate geometrically and radiometrically accurate light detection and ranging (LiDAR) data, producing ground 3D (structural) truth data that would be nearly impossible to collect in complex forest environments. DIRSIG was leveraged to understand the nuances of a simulated forest, specifically Harvard Forest in Petersham, MA (Figure 1). This simulated forest included various materials such as bark, leaves, soil, and miscellaneous objects. LiDAR systems (airborne and spaceborne), which are useful for penetrating sub-canopy layers, were configured to collect LiDAR data. The resulting data sets provide valuable insights into forest health and sub-canopy intricacies, with applications in target detection, environmental monitoring, and forest management.

Project Status

The LiDAR point cloud data were converted into a 3D grid representation (voxels) of different sizes, which allows for optimal efficiency, storage, and more affordable computational expenses. The problem of sub-canopy forest characterization was approached in two ways: as a classification problem where each voxel is assigned a label, and as a regression problem, where voxel contents are estimated in terms of their percentage contribution to the voxel. We utilized deep models such as Point-Voxel CNN, and VoxNet, along with upsampling techniques to ensure unbiased training for the classification approach. Kernel Point Cloud (KPConv; Figure 2) convolutions aided by imbalance metrics was used for reliable performance evaluation.

The findings were promising, with the classification approach for the achieving multi-class accuracy metrics of 86% precision and 74% recall. The voxel content estimation approach revealed a trade-off between voxel size and forest complexity, identifying an optimal voxel size of 1 meter as a balance between the two, with regression coefficient of determination as high as 0.54 for bark and leaf voxels and 0.35 for objects. These results underscore the potential of using DIRSIG-generated LiDAR data for detailed forest analysis, paving the way for more precise and comprehensive environmental studies.

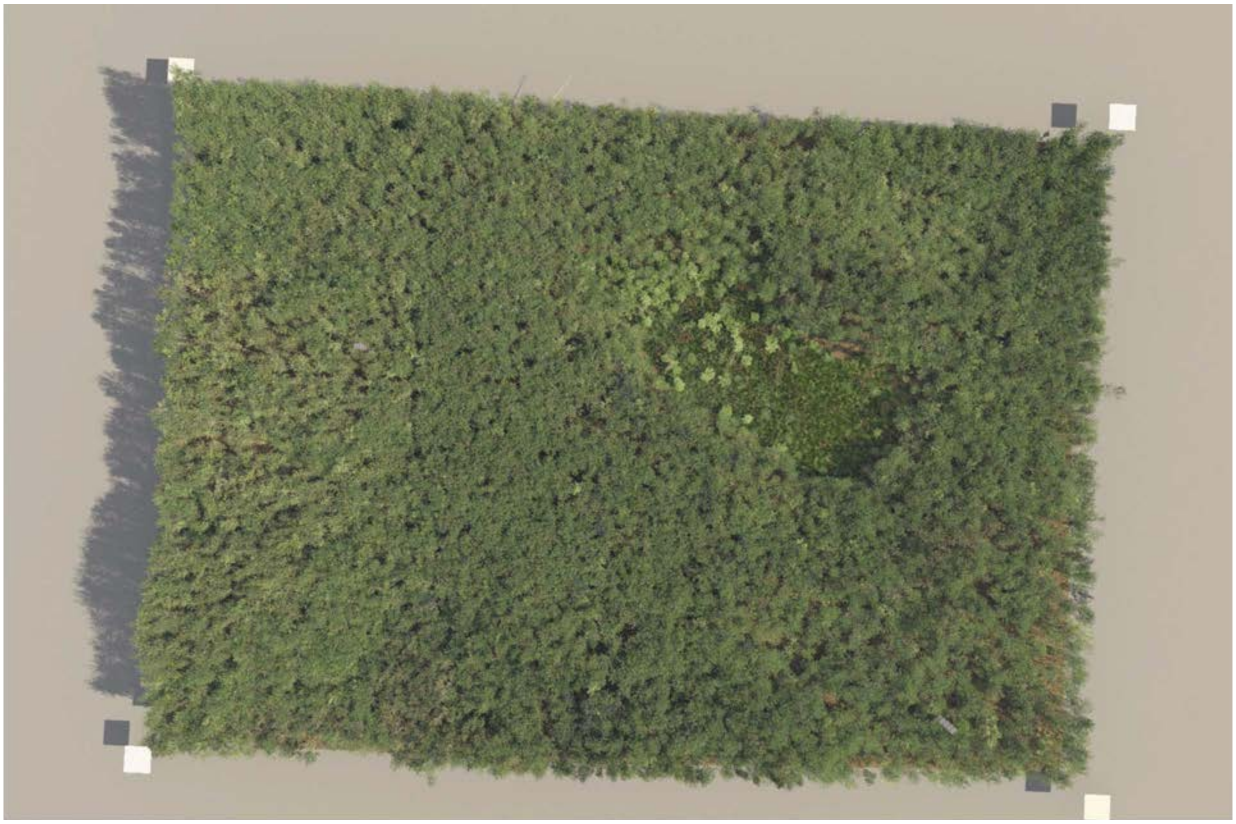


Figure 1: Nadir view of the simulated Harvard Forest Scene. Size of the scene is 500x700 meters

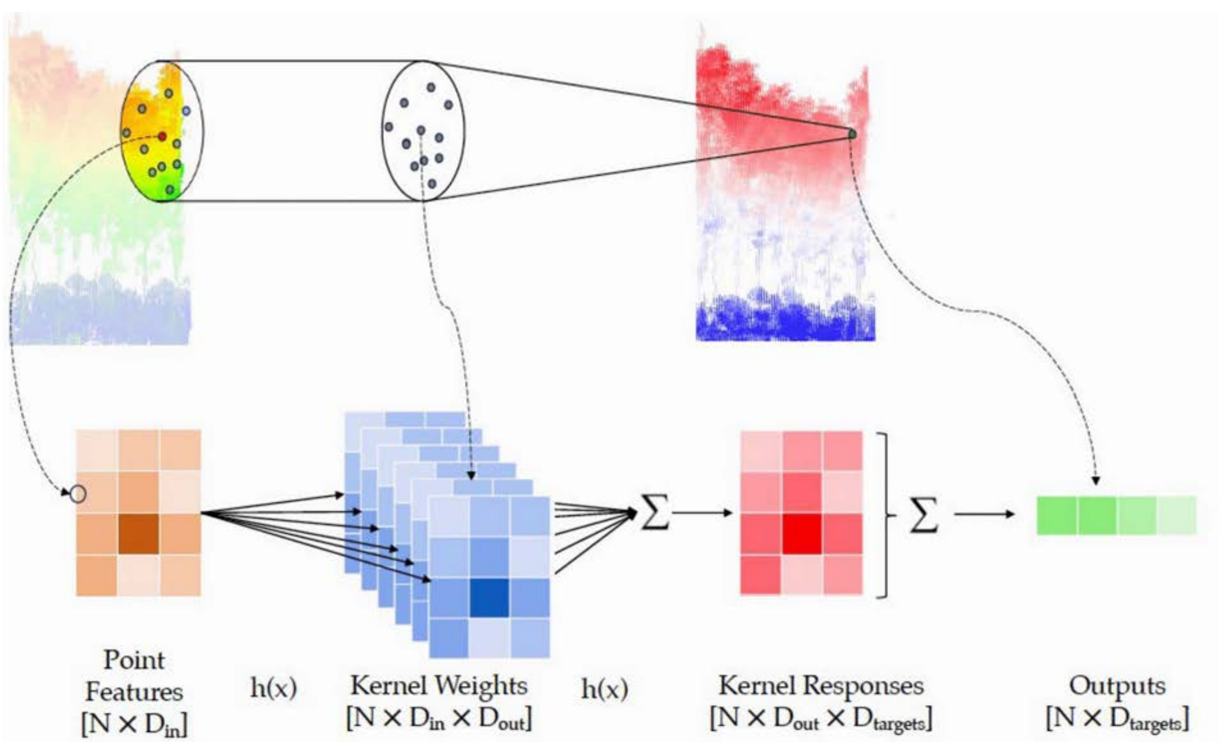


Figure 2: KPConv Architecture adapted for multi-target regression task and voxel content estimation.

The influence of canopy structure and foliar chemistry on remote sensing observations: radiative transfer modeling to understand interactions of light within the canopy and inform innovative uses of remote sensing data

Sponsors: NASA (Remote Sensing Theory)

Principal Investigator: Jan van Aardt

Team: Kedar Patki, Rob Wible, Grady Saunders, Dr. Keith Krause (Battelle), Dr. Scott Ollinger (University of New Hampshire; UNH), Andrew Ouimette (UNH), and Jack Hastings (UNH)

Project Description

The objectives of this project are to i) better understand the correlations between spectral reflectance and structural metrics and structure-trait cause-and-effect relationships; ii) propose a data fusion approach (LiDAR + hyperspectral) to trait prediction; and iii) apply the fusion approach to mitigate scaling issues (leaf-level, stand-level, forest-level). We are currently focusing our efforts towards understanding impact on spectral and structural metrics due to variation in leaf angle distributions (LAD). Leaf angle is a key factor in determining arrangement of leaves, and directly impacts forest structural metrics, such as leaf area index (LAI), which in turn is an important variable for a variety of ecological processes, such as photosynthesis and carbon cycling.

Project Status

In previous research, we qualitatively showed the changes induced in several important vegetation and LiDAR indices - NDVI, PRI, REIP, Canopy height, and Intensity Ratio. We further performed a more robust quantitative comparison for several different vegetation indices over changes in underlying leaf angle distributions using the Kolmogorov-Smirnov test. The vegetation indices shown here are NDVI, PRI, OSAVI, and TCARI/OSAVI, all of which are well known in vegetation remote sensing literature for their sensitivity for plant chlorophyll content. As shown in Figure 1, although all indices show change in their distributions, TCARI/OSAVI and PRI exhibit relatively less sensitivity to changes in LADs; TCARI/OSAVI shows strong similarity for higher leaf angle distributions, whereas PRI also indicates strong similarity in distributions for lower angles based on the KS test p-values. These indices thus are better suited for index-based predictions in a mixed forest setting.

We next used the DIRSIG Harvard Forest 3D model geometry information to calculate ground truth values for LAI and chlorophyll content. We divided our 3D scene into 1m x 1m x 1m voxels and accumulated areas of all leaf elements (made of triangular primitives) within each voxel. We then accumulated the leaf areas in each voxel column and divided these by the voxel face area (pixel size) to obtain LAI. Similarly, for chlorophyll content values, we calculated leaf area per voxel column for each plant species (separate material IDs for each species) individually. For each material ID, we have a unique spectrum which we inverted using PROSPECT to obtain a chlorophyll concentration value. We then took a weighted average over all spectra and obtained the chlorophyll content for each voxel. Figure 2 shows a full voxel summation, as well as a partial voxel summation, from 2 m above ground level and upwards, which is more representative of the height above ground where a handheld sensor would be used in a real forest measurement for LAI. Also shown is a plot of full and partial voxel sum LAIs.

Ongoing work includes statistical modeling using classical ML methods known to work well for LAI and canopy chlorophyll estimation - SVR, PLS, and RF regression. We aim to show how the predictions from these models can also be impacted by changes in leaf angle distributions. Further, our goal is to incorporate structural information with DIRSIG LiDAR simulations for more robust LAI and chlorophyll predictions.

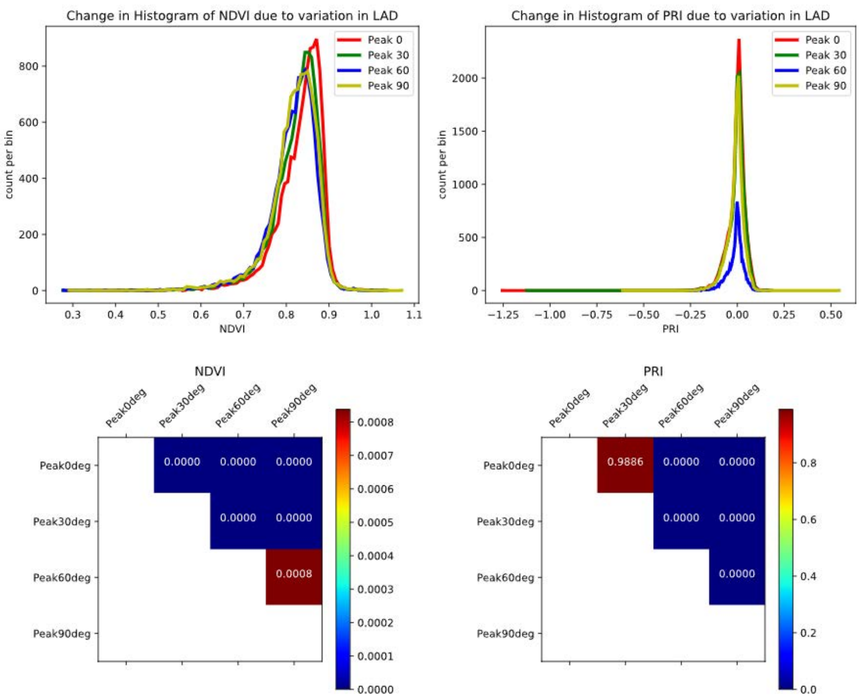


Figure 1.1: Change in distribution of four different vegetation indices due to variation in Leaf Angle Distribution, along with distribution similarities quantified using KS test p-values

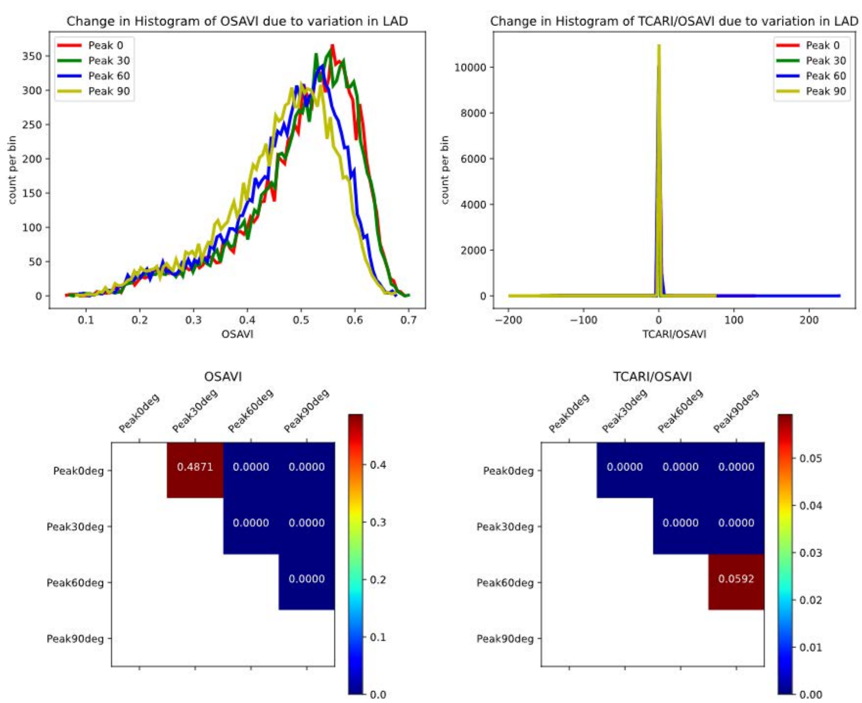


Figure 1.2: Change in distribution of four different vegetation indices due to variation in Leaf Angle Distribution, along with distribution similarities quantified using KS test p-values

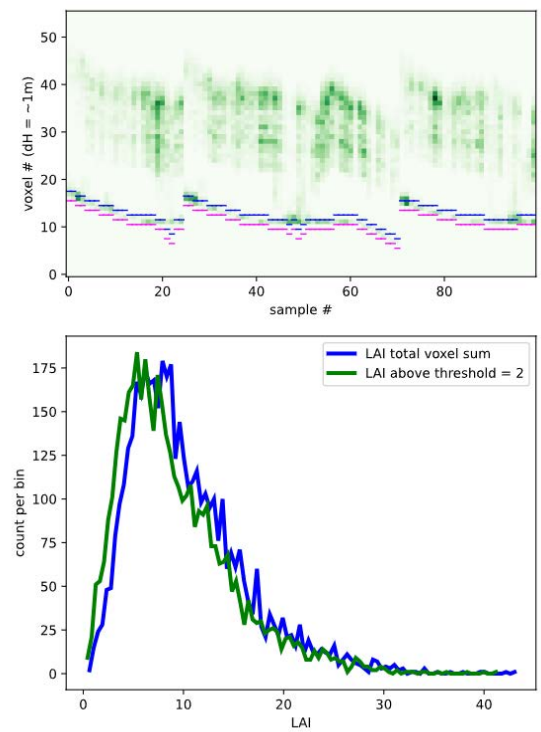


Figure2: Leaf area vertical distributions shown for a few sample voxels, along with Ground Truth distribution obtained from Harvard Forest 3D model

Globally-Derived Measures of Structure Informed by Ecological Theory and Observation

Sponsors: NASA (Decadal Survey Incubation)

Principal Investigator: Jan van Aardt

Team: Tahrir Siddiqui

Project Description

Accurate, large-scale estimation of forest productivity, representing the accumulation of plant biomass over time, is essential for measuring carbon flux in forests, quantifying the impact of reforestation initiatives, and assessing forest ecosystem health. Ecological studies have revealed a strong positive linkage between forest productivity and canopy structural complexity (CSC) metrics derived from portable canopy lidar (PCL) data. However, terrestrial scanners such as PCL are limited in spatial coverage and cannot be used to scale up forest productivity estimates across landscape to biome-wide scales. Aerial laser scanning (ALS), on the other hand, offers a way to rapidly capture CSC traits across large, contiguous forested regions. Despite this potential, the capability of ALS to capture forest CSC traits closely linked to productivity is yet to be investigated.

The objectives of this project thus are to i) identify existing and novel forest structural metrics, akin to leaf area index (LAI), that are strongly correlated with ecosystem function and broadly useful to advancing ecological knowledge at multiple spatial scales; ii) design and develop the suite of "next-generation" light detection and ranging (LiDAR) instruments and processing algorithms for deriving ecologically-significant vegetation structural metrics; iii) assess the capabilities and limitations of current LiDAR systems to produce ecologically-meaningful next-generational data products; and iv) evaluate the accuracy and uncertainty of next-generation data products across several spatial scales, including change across time.

We addressed the identified knowledge gaps by proposing a novel suite of three-dimensional (3D) CSC metrics derived from small-footprint ALS data, acquired by the National Ecological Observatory Network's (NEON) Airborne Observation Platform (AOP), for modelling net primary production (NPP) in 1) deciduous forests, 2) evergreen forests, and 3) all forest types (deciduous + evergreen + mixed), across six ecoclimatic domains in the continental United States. Figure 1 shows the approach and associated metrics.

Project Status

We employed a combination of partial least squares (PLS) regression with cross-validation (PLS-CV) and recursive feature elimination (RFE) to identify candidate models, selecting the best one based on the corrected Akaike information criteria (AICc) scores. We then eliminated redundant variables (Pearson correlation > 0.90) and statistically-insignificant variables (p-value > 0.05) from the best candidate models. Finally, we tested all statistically-significant resolutions at which the selected scale-sensitive CSC metrics were derived (Figure 2 shows the workflow). The best model for each forest type explained a high amount of variance in NPP, with three CSC metrics explaining 77% of variance in deciduous forests (RMSE% = 11%) and three CSC metrics accounting for 76% of variance in evergreen forests (RMSE% = 13%; see Figure 3). However, no statistically-significant candidate models were identified for all forest types combined, underscoring that CSC predictors driving NPP vary with canopy architecture (deciduous vs. evergreen). The 3D CSC metrics identified as strong predictors of NPP in our study hold significant potential for enabling accurate biome-wide estimation of carbon sequestration in temperate deciduous and evergreen forests using small-footprint ALS data.

We are currently preparing the manuscript for submission to Elsevier's Remote Sensing of Environment journal. In the next stage of the project, we will develop modelling methods to accurately retrieve the identified 3D CSC metrics from large-footprint waveform data, towards identifying the optimal space-based LiDAR system for capturing these target metrics.

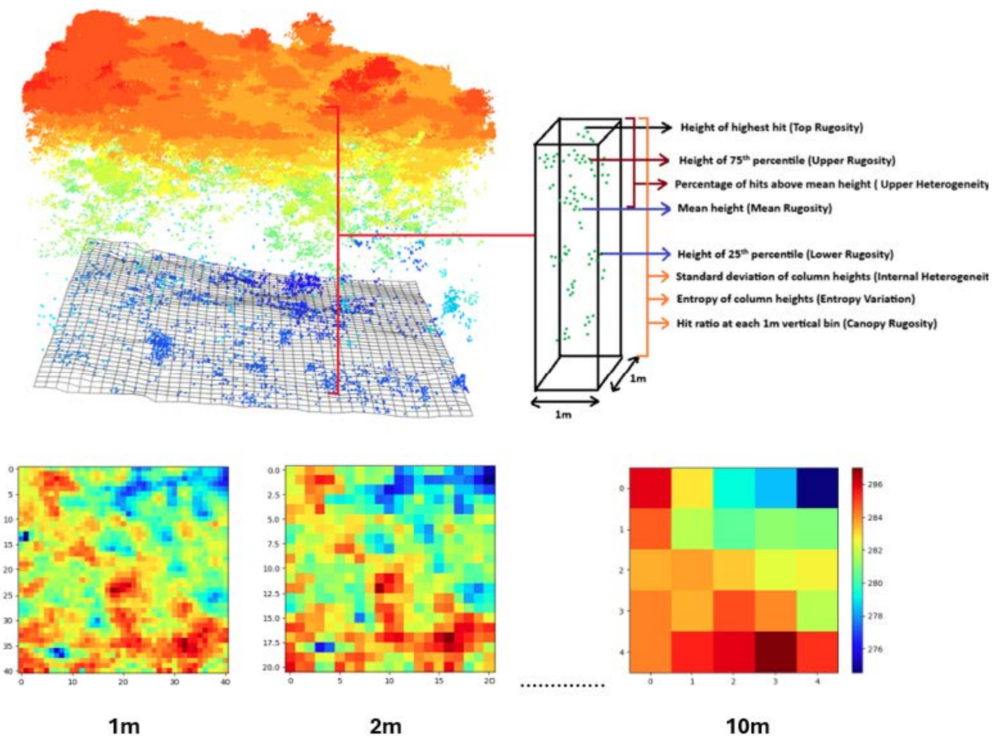


Figure 1 illustrates the derivation of our raster-based 3D CSC metrics. Eight out of nine metrics we derived are raster-based. Top: A column from the point cloud of a forest plot gridded at 1m2 resolution. Portions of the canopy described by the computed raster values are labelled, along with the corresponding metric in parenthesis. Bottom: Raster-based metrics were computed from 1-10m spatial resolution in each 40x40m plot to assess scale-sensitivity.

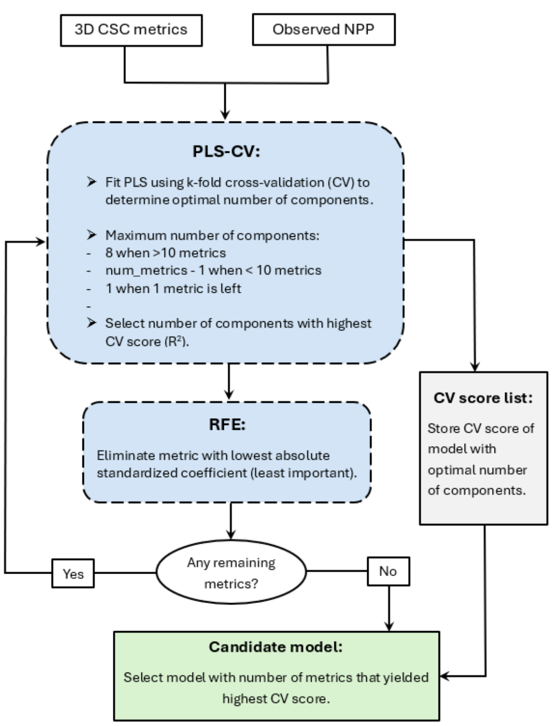


Figure 2 illustrates our PLS-CV + RFE approach for modelling NPP using 3D CSC metrics and identifying candidate models.

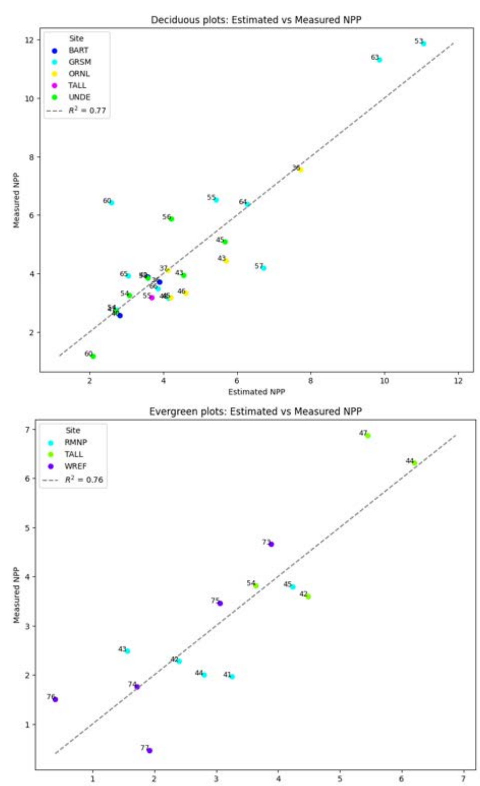


Figure 3 Top: Fit for best deciduous model. Bottom: Fit for best evergreen model.

Vicarious Radiometric Calibration of Satellites using Mirrors

Sponsors: Labsphere, Inc.

Principal Investigator: Emmett Ientilucci

Team: David Conran

Project Description

The SPecular Array Radiometric Calibration (SPARC) method employs convex mirrors to create field deployable radiometric and spatial calibration targets for remote imaging sensors. Recent research has been invested into understanding the use of convex mirrors to assess the image and data quality of drone mounted hyperspectral imaging (HSI) systems. To fully understand our scientific applications with such instruments, radiometric and spatial characterizations need to be conducted under similar field conditions which makes convex mirrors an optimal target for extracting pixel level discrepancies. Hyperspectral imaging systems frequently rely on spectral rather than spatial resolving power for identifying objects within a scene. A hyperspectral imaging systems response to point targets under flight conditions provides a novel technique for extracting system-level radiometric performance that is comparable sub-pixel spatial unresolved objects. The system-level analysis not only provides a method for verifying radiometric calibration during flight, but also allows for the exploration into the impacts on small target radiometry, post orthorectification. Standard Lambertian panels do not provide similar insight due to the insensitivity of orthorectification over a uniform area.

Project Status

In our latest work, we utilize a fix-mounted hyperspectral imaging system (radiometrically calibrated) to assess 8 individual point targets over 18 drone flight overpasses. Of the 144 total observations, only 18.1% or 26 instances were estimated to be within the uncertainty of the predicted entrance aperture-reaching radiance signal. For completeness, the repeatability of Lambertian and point targets were compared over the 18 overpasses where the effects of orthorectification drastically impacted the radiometric estimate of point targets. The unique characteristic point targets offer, being both a known spatial and radiometric source, is that they are the only field-deployable method for understanding the small target radiometric performance of drone-based hyperspectral imaging systems. These findings were published in the journal of Remote Sensing.

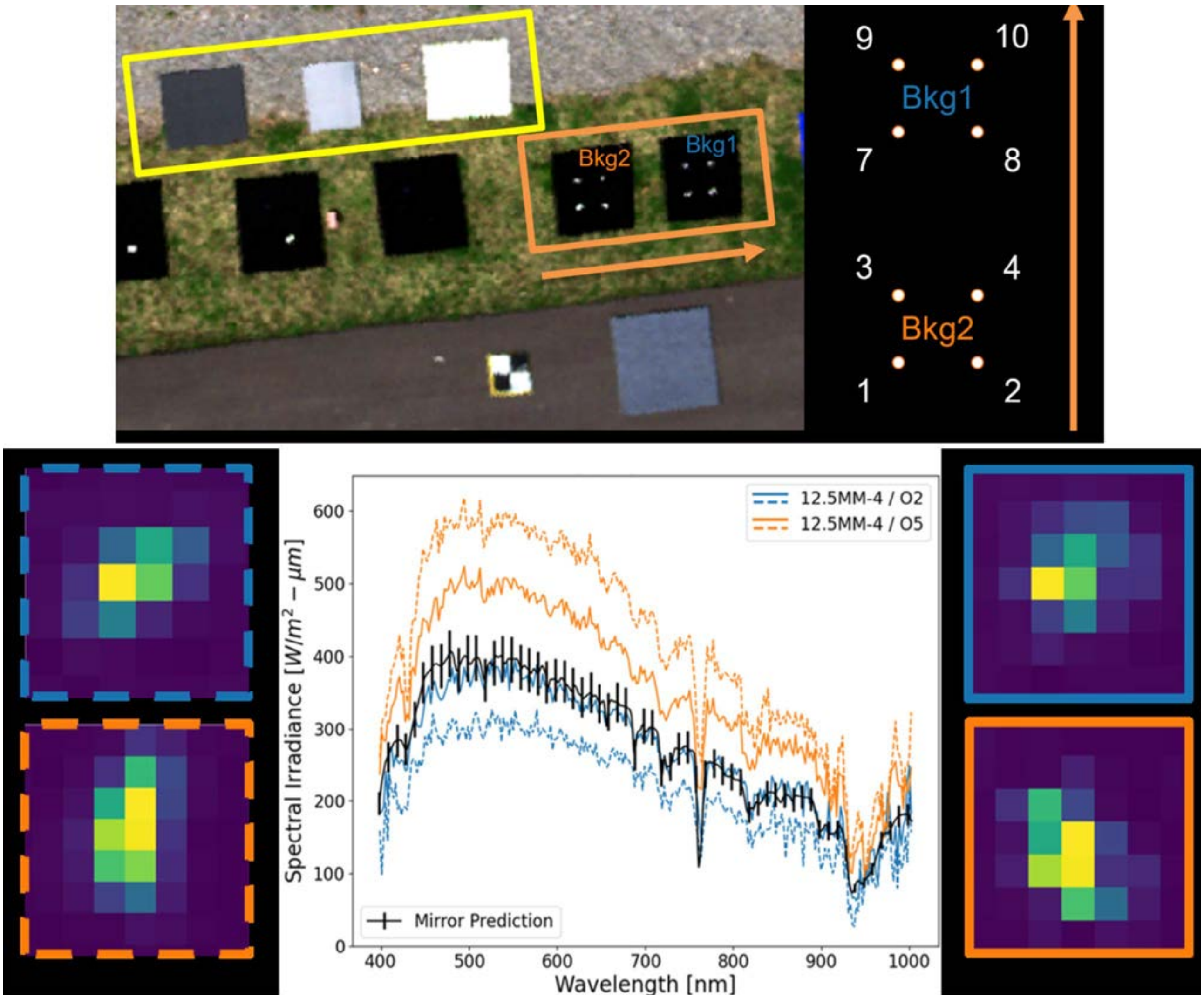


Figure 1: (top) The Lambertian targets are within the yellow box and the point targets (i.e., convex mirrors) are within the orange box. The orange arrow in both images helps define mirror placement within the imagery. The black right-side graphic depicts mirror placement and assigned mirror ID which is linked to descriptive mirror properties and subsequent results. (bottom) A point target, from the top graphic, imaged at overpass #2 and overpass #5 signifies the radiometric inconsistency when observing a point target in quick secession. The blue curve is measured within the uncertainty (black bars) whereas the orange curve is now over-predicted. Platform motion and orthorectification contribute to these inconsistencies. The dotted and solid curves correspond to the unorthorectified and orthorectified point targets, respectively.

L'Ralph In-flight Instrument Characterization

Sponsor: NASA Goddard Space Flight Center

Principal Investigator: Matthew Montanaro

External Collaborators: NASA Goddard Space Flight Center

Project Description

The in-flight characterization and calibration of NASA's Lucy Ralph (L'Ralph) instrument is essential to a successful science mission. The L'Ralph instrument will provide spectral image data of the Jupiter Trojan asteroids from visible to mid-infrared wavelengths from two focal planes sharing a common optical system. The Multispectral Visible Imaging Camera (MVIC) acquires high spatial and broadband multispectral images in the 0.4 to 0.9 micron region. The Linear Etalon Imaging Spectral Array (LEISA) provides high spectral resolution image data in the 1 to 3.8 micron spectral range. The Lucy observatory is currently in flight (phase E) after a successful launch in October 2021 and is in-route to the Jupiter Trojan swarms via multiple Earth Gravity Assists (EGAs). The overall objective of this work is to assist in the continuing characterization and radiometric calibration of the L'Ralph instrument through processing and analyses of in-flight image data. These image datasets are assessed for radiometric and spatial quality. Calibration algorithms are updated as needed to correct any artifacts or radiometric errors found during these image assessments.

Project Status

Following a gravity assist from Earth in Oct 2022, the Lucy spacecraft's new orbit extends deep into the asteroid belt. The mission encountered its first asteroid, 152830 Dinkinesh, in Nov 2023 with the L'Ralph instrument acquiring several image scans of the object. The PI assisted in image processing of these scans along with characterizing the instrument performance during the encounter. The PI helped develop an algorithm to correct for an optical fringing artifact observed in all image data from the L'Ralph/LEISA detector array. This algorithm will be part of the standard processing pipeline that generates L'Ralph products for the Planetary Data System deliveries. The Lucy mission is on target for the second gravity assist of Earth in Dec 2024 to set up encounters with the Jupiter Trojan asteroids later this decade. The PI will continue to review in-flight calibration data to prepare for upcoming asteroid encounters.

Figure 1: Image of main-belt asteroid, Dinkinesh, and its previously unknown moon, Selam, acquired by the L'Ralph MVIC detector arrays in Nov 2023. Color composite created from the MVIC violet, green, and orange channels. Image reproduced by the PI and originally processed by Dr. Amy Simon, NASA GSFC, for the article: https://blogs.nasa.gov/lucy/2023/11/29/satellite-discovered-by-nasas-lucy-mission-gets-name/

Improved Strategies to Enhance Calibration and Validation of Landsat Thermal Data and Their Associated Higher-Level Products

Sponsor: United States Geological Survey, Earth Resources Observation and Science Center

Principal Investigator: Aaron Gerace

Team: Rehman Eon, Amirhossein Hassanzadeh, Nina Raqueno

Students: Elphas Khata, Austin Martinez, Christian Secular, Sebastian Steigerwald, Zachary Steigerwald, Brandon Burton, Aries Ho, Deepak Talapaneni

Project Description

This research effort leverages existing techniques to support persistent calibration of Landsat's operational thermal instrumentation and to continue the development and validation of their corresponding surface temperature products, see Figure 1. Considering the scarcity of thermal reference data due to insufficient ground-based equipment, significant effort has been placed on the development of a multichannel thermal radiometer to support Landsat Surface Temperature product validation.

Project Status

This five-year effort concludes in September 2024. RIT has worked with USGS-EROS to implement an operational (near real-time) surface temperature workflow in their Landsat Product Generation System (LPGS) that uses data acquired from the Thermal infrared Sensors (TIRS-1 and TIRS-2) onboard Landsat 8 (9). Once active, Landsat products that leverage the split window algorithm for deriving surface temperature will be made freely available to users worldwide. Several studies that use existing ground-based equipment for reference continue to be conducted to characterize the fidelity of the Landsat surface temperature products. To address the scarcity of thermal reference data in the community, RIT continues to investigate the feasibility of a lost-cost thermal radiometer design to potentially increase the reference measurements available for validation. Results from in-lab calibration indicate that the units are performing as expected. Field-data are currently being acquired and comparisons being made to Landsat's surface temperature products to assess the utility of these ground-based instrumentation for validating spaceborne products. Figure 2 shows the current radiometer being characterized in an environmental chamber (left) and in the field equipped with environmental sensors (right).

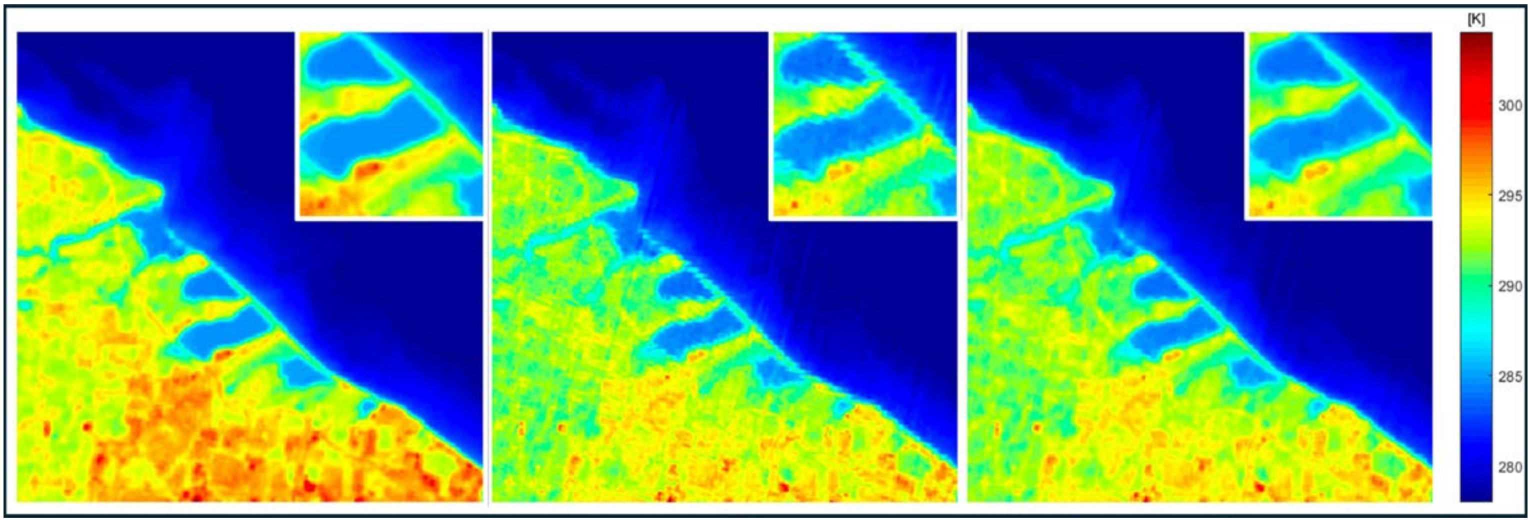


Figure 1: Surface temperature products derived from TIRS data acquired over the Rochester embayment using the Single Channel algorithm (left), nominal Split Window algorithm (middle) and modified Split Window algorithm (right).

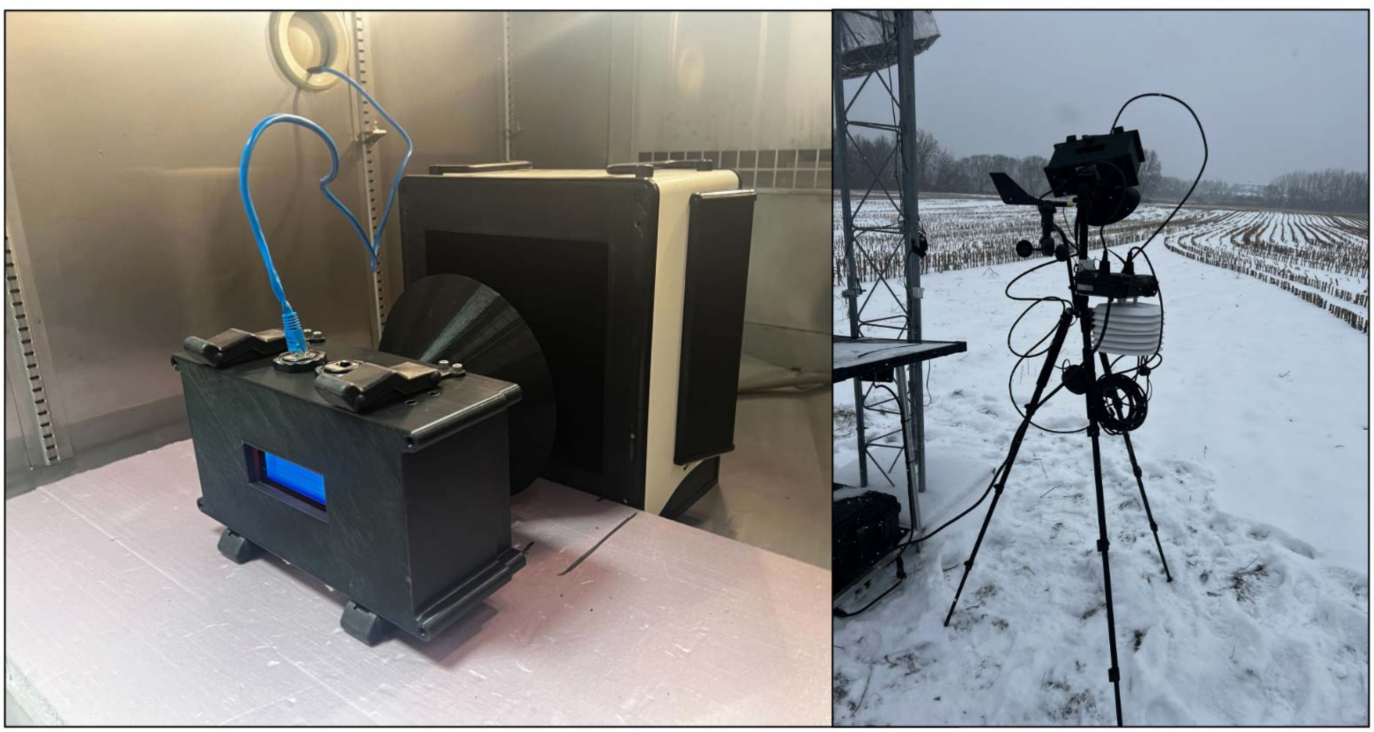


Figure 2: The thermal radiometer developed at RIT for measuring kinetic surface temperature to support Landsat surface temperature product validation. (Left) shows the radiometer being characterized in an environmental chamber and (right) shows the unit integrated with environmental sensors in the field.

Landsat Thermal Imaging Systems

Sponsor: NASA Goddard Space Flight Center

Principal Investigator: Matthew Montanaro

Team: Aaron Gerace, Rehman Eon, Amir Hassanzadeh

External Collaborators: NASA Goddard Space Flight Center, U.S. Geological Survey (Earth Resources Observation and Science Center)

Project Description

This project provides general image calibration and systems support for the Landsat thermal band instruments for NASA. Specifically, this involves the continuing on-orbit characterization and calibration of the Landsat 8 / Thermal Infrared Sensor (TIRS) and the Landsat 9 / Thermal Infrared Sensor 2 (TIRS-2) instruments. It also involves instrument architecture and requirements assessments for the upcoming Landsat Next mission. The PI serves on the Calibration and Validation team for the Landsat program and is the Deputy Instrument Scientist for the Landsat Next project. Team members also provide technical expertise and guidance on Landsat thermal image products to the Landsat Science team and the US Geological Survey (USGS).

Project Status

Over the past year, the PI has been primarily involved in image data compression studies to determine how best to downlink all science data from the Landsat Next mission. He helped explore the compression algorithm with real and simulated image data and helped converge on a set of parameters that would allow science data to fit within the available downlink data rate, yet still maintain science quality requirements. He also opened a dialogue with the European Space Agency to coordinate compression efforts with their upcoming Sentinel 2 Next Generation system. The PI continued to support the on-going operations of the TIRS instruments onboard Landsat 8 and Landsat 9 through analyses of in-flight calibration data with the Landsat Cal/Val team and by assisting the Flight Operations team with recovering from instrument anomalies.

Team members continued to support USGS efforts to field a Landsat land surface temperature product by providing USGS engineers with requested test data and algorithms. The team also continued to provide modeling support and expertise for Landsat Next science product and compression studies.

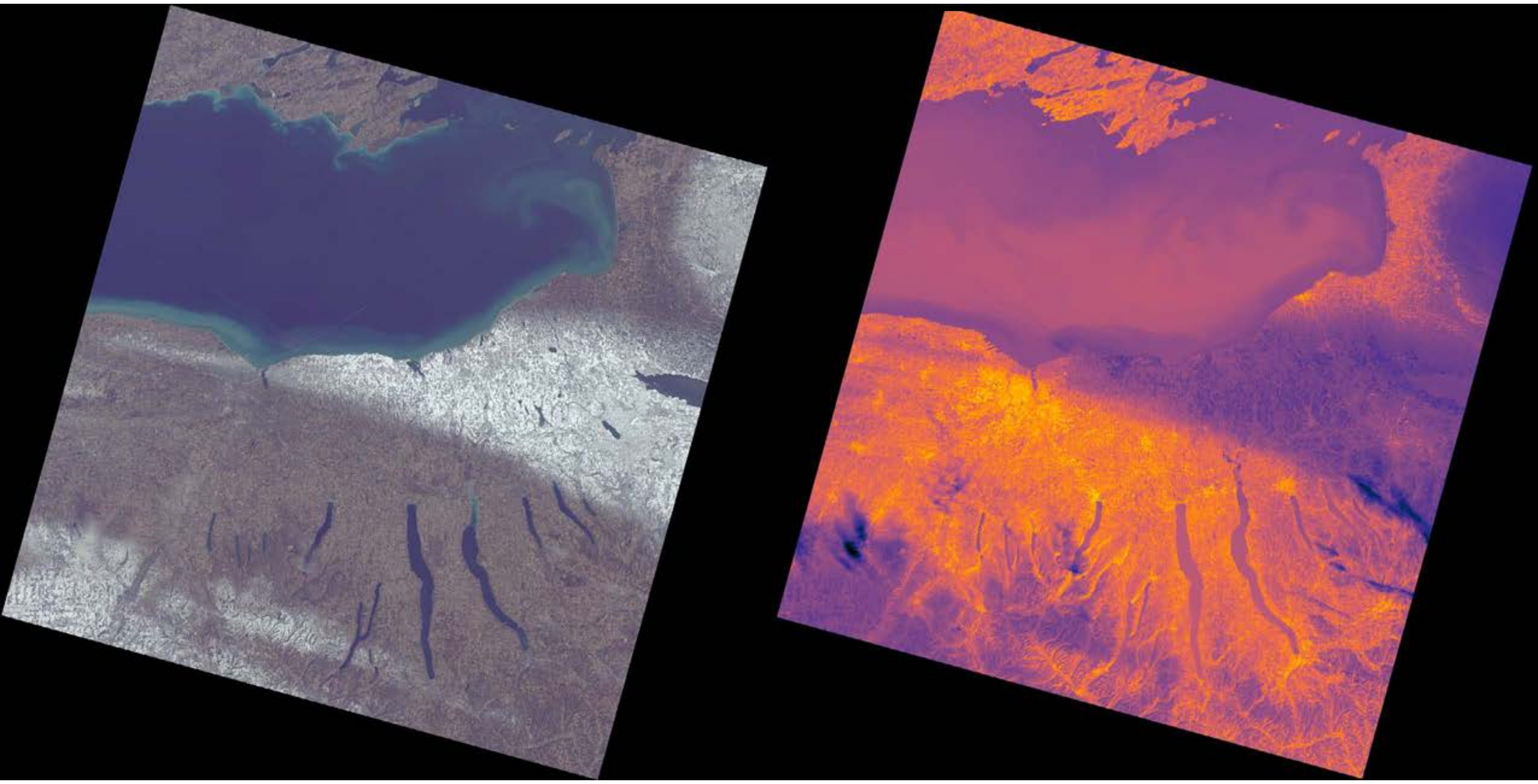


Figure 1: USGS product images from the Landsat 9 / OLI-2 instrument (left, in natural color) and from the Landsat 9 / TIRS-2 instrument (right, in thermal false color). This area of Western NY State captures a lake effect snow band from Lake Ontario between Rochester and Syracuse. For the thermal image, orange colors represent warmer temperatures vs. purple colors for cooler temperatures. Image width is 185 km with a pixel ground resolution of 30 meters (resampled from 100 meters for the thermal image). North is straight up. Acquired on 2024-03-01.

Solar Cruiser RCD Radiometry

Sponsor: NASA

Principal Investigator: Charles M. Bachmann

Research Staff: Chris H. Lee, Nayma Binte Nur, Dylan Shiltz, Christopher Lapszynski

External Collaborator: Dr. David Smith (NASA Marshall)

Project Description

Our project supported the objectives of the NASA Solar Cruiser Reflective Control Device (RCD) Radiometry activity by providing expertise and measurement capabilities in radiometry. We specifically evaluated candidate RCD samples in both on and off states using both polarized and unpolarized hyperspectral bidirectional reflectance distribution function (BRDF) measurements that span the majority of the solar spectrum and viewing hemisphere, acquiring this data with our hyperspectral goniometer. From these measurements the non-Lambertian coefficient, as well as specular, diffuse, and total hemispherical reflection are determined at each incidence angle. These coefficients have been used as input into a solar radiation force model that takes into account sail shape, to determine whether the corresponding RCD area would meet Solar Cruiser mission requirements for roll control.

Project Status

This project constitued the second set ofmeasurements that we have taken in our laboratory using our hyperspectral goniometer system [1] in support of the NASA Solar Cruiser program. As RCD designs have been improved, we have taken measurements to fully characterize their BRDF over the observation hemisphere for a variety of illumination angles, measuring both polarimetric and unpolarized BRDF for provided samples in both on and off states. NASA has incorporated these measurements into their solar radiation force models for the Solar CruiserProgram [2]. Additional measurements are planned in a new project as the design continues to improve.

Figure 1: (Top) Our hyperspectral goniometer system (GRIT-T) [1] during BRDF measurements of the RCD, showing (right) close-ups of the linear polarization filter attached to the spectrometer fore-optic during a polarimetric BRDF scan.

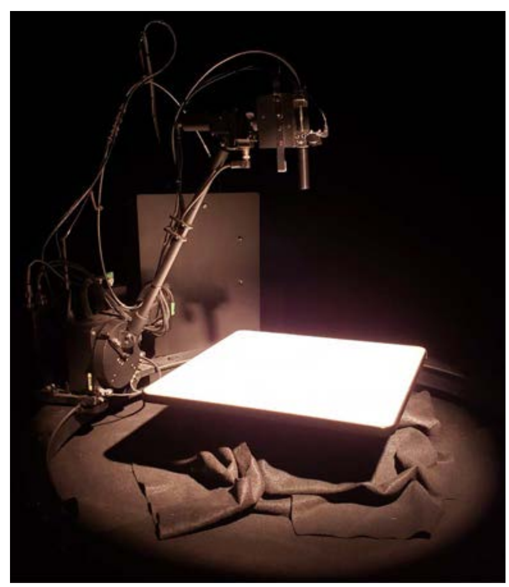


Figure 2: GRIT-T measurements of the SpectralonTM reference panel.

Enhancing spatial resolution of airborne hyperspectral systems

Sponsors: Department of Defense, National Geospatial-Intelligence University Research Initiative (NURI)

Principal Investigator: David Messinger

Team: Jose Macalintl, Ph.D. candidate, Sihan Huang, Ph.D., Rey Ducay, Ph.D., Amir Hassanzadeh, Ph.D.

Project Description

Our current work looks at ways to enhance the spatial resolution of airborne hyperspectral systems by fusing the data with higher spatial resolution panchromatic and multispectral images. Additionally, we are working at fusing high resolution Vis-NIR Hyperspectal imagery with lower spatial resolution SWIR HSI to produce full spectrum cubes from the current deployment setup in which the two sensors are flown on separate platforms. The key here is not to produce visually pleasing pictures with good color balance as is traditionally done, but to produce radiometrically accurate spectral information that can be used in further processing. This is important because hyperspectral imaging is not typically visually analyzed, but rather, algorithms that leverage the spectral information in the scene, sometimes combined with point measurements taken by different instruments, are used to tasks such as classification and target detection. Consequently, providing accurate radiometry is of high importance.

Project Status

Our approaches have been two-fold. In the first, novel algorithms have been developed based on artificial intelligence and machine learning approaches, particularly unsupervised approaches that require no training data. These methods in general are trying to learn an approximation to a non-linear transformation of some sort, which is well suited to this problem as the radiometric, optical, and sampling processes in hyperspectral imaging systems are generally non-linear. We also require unsupervised methods such that the approaches can be used for scenes imaged for the first time, so no training data are available. Methods have been developed that sharpen HSI in both the Visible-Near Infrared spectral range (Vis-NIR, approximately 400 nm to 1,000 nm) as well as going further out into the Short Wave Infrared (SWIR, approximately 2,500 nm) where there is typically no high resolution data. These methods work very well but have a very large computational cost which limits their practical implementation.

On the other hand, we have taken another approach to expand on a “traditional” sharpening algorithm to extend it beyond panchromatic and multispectral imagery to be used to sharpen hyperspectral imagery. The method, termed NNDiffuse (for Nearest Neighbor Diffusion) was originally developed to sharpen multispectral satellite based imagery using co-temporal panchromatic imagery. Here, we extend it to an image fusion approach, fusing the high spatial resolution information from multispectral imagery with low spatial resolution hyperspectral imagery. Of key interest here is the use of spatial features to enhance the sharpening process. Essentially, by understanding where there are spatial edges in the scene, we can “control” the diffusion process to better represent the material borders on the ground. This approach, while not as radiometrically accurate as the AI/ML approach described above, still produces good results and is computationally very simple and fast, providing an algorithm that can be implemented into standard processing workflows.

Our latest work focuses on the common deployment scenario in which the two HSI sensors are operated from separate platforms, producing two cubes of the same scene, at different spatial resolutions, but with some spectral overlap. This works seeks to both spatially align the cubes, a significant challenge from relatively unstable platforms such as UAS’s, as well to spectrally align the measurements. The end goal is to produce one spatially aligned, radiometrically accurate cube at the highest resolution possible.

LandIS

Sponsor: NASA Goddard Space Flight Center

Principal Investigator: Rehman Eon

Team: Matthew Montanaro, Aaron Gerace, Amir Hassanzadeh, Adam Goodenough

Project Description

The Landsat Next Instrument Suite (LandIS) is committed to extend the nearly fifty-year data record of spaceborne measurements of the Earth's surface collected from Landsat's reflective and thermal instruments. The goal of the LandIS mission is to continue the mission of the Landsat program for acquisition, archival, and distribution of imagery to characterize decadal changes in the Earth's surface. LandIS will consist of a constellation of three satellites, which will provide an improved temporal revisit (a six-day revisit) for the purpose of monitoring dynamic changes in the Earth's surface. The sensor will also be a significant change in the number of spectral bands compared to its predecessors - Landsat 8/9 - which currently consists of 11 spectral bands at 30-m GSD. While, LandIS will have a total of 26 spectral bands at Ground Sample Distance (GSD) of 10-m, 20-m and 60-m. This will result in a significantly higher data volume compared to its predecessor. This increase in data will require a more efficient compression algorithm currently being implemented for L9; a lossless compression algorithm based on the Consultative Committee for Space Data Systems (CCSDS) 121.0 recommendation standard. After exploring available options, CCSDS-123.0 B2 emerged as the top choice. This open compression standard provides high-performance lossless and near-lossless compression, crucial for maintaining data integrity in scientific applications.

Project Status

The image compression is being performed via the protocol set by the Consultative Committee for Space Data Systems (CCSDS). The CCSDS released the CCSDS 123.0-B-2 standard, "Low-Complexity Lossless and Near-Lossless Multispectral and Hyperspectral Image Compression", which includes the addition of near-lossless compression. The standard allows for lossy compression of imagery with user-defined absolute and/or relative error limits in the reconstructed images. In this study, we examined the feasibility of using both absolute error and relative error modes for compressing the proxy data. User-specified settings for absolute and/or relative error limits enable control over the percentage of error in the reconstructed image samples. These parameters can be adjusted to balance reconstructed image fidelity against the desired compression ratio. An example of the impact of the two different lossy compression method on a proxy-LandIS band 16 (1080-1100 nm) image simulated using DIRSIG is shown in Figures 1 and 2. Figure 1 provides a visualization on the error magnitude of the image reconstructed using the two lossy compression settings. Figure 2 shows the histogram of the absolute error and percent difference error as a function of DN for both absolute/relative error. Controlling the loss fidelity using absolute error limits produce a nearly uniformly distributed reconstruction error, with a maximum error (m) of ±4 DN uniformly distributed throughout the data (Figure 2). In contrast, the relative error limit introduces error scaled based on the scene content, resulting in smaller errors in lake and shaded regions and higher errors in other regions, especially in bright city areas. Controlling fidelity via relative error limits allows the user to manage the amount of error present in the data based on percentage error. On the other hand, the absolute error limit tends to produce high percentage errors at lower DN values. The advantage of using relative error is also evident in the visualization in Figure 2, where the reconstructed image is lossless over lower DN values, such as water, thereby maintaining the fidelity of the data for scientific applications. The existing archival Landsat 9 data was also used to create global maps of compression ratios that can achieved using the relative error mode, which is shown in Figure 3.

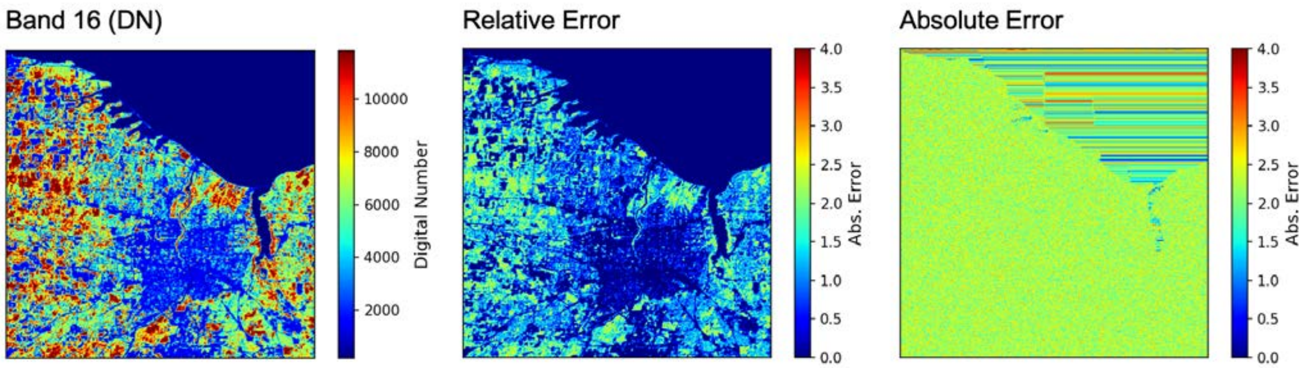


Figure 1: The absolute error magnitude on the reconstructed image due to relative and absolute error limit compression.

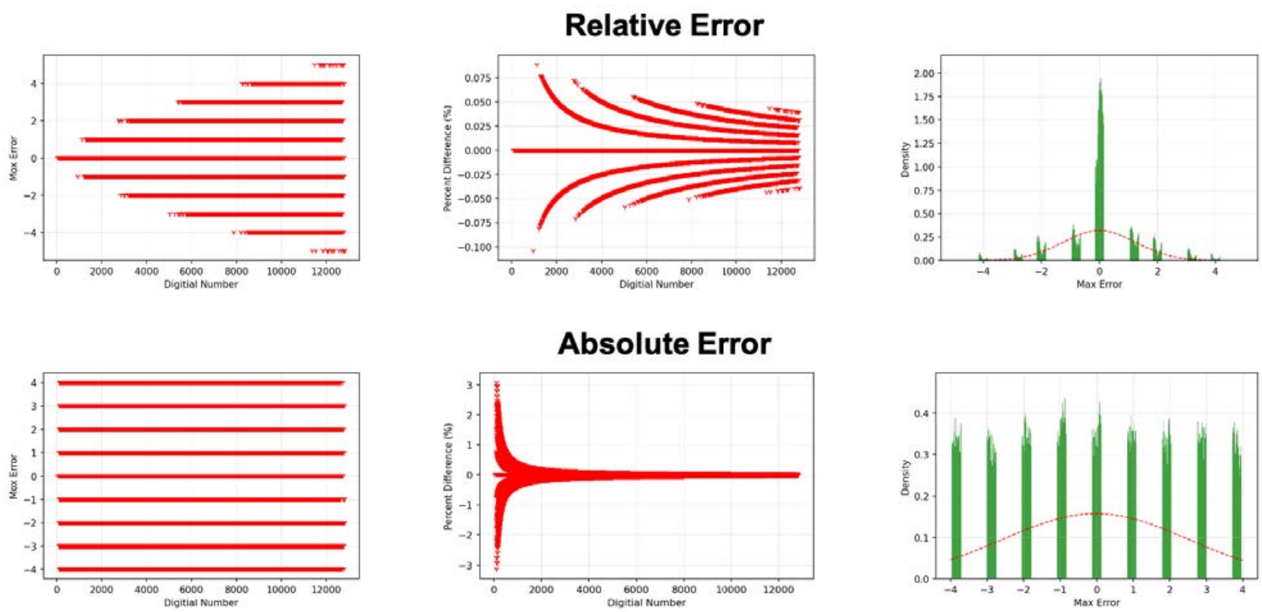


Figure 2: Histogram of the reconstructed error in the image after compression due to relative and absolute error limit.

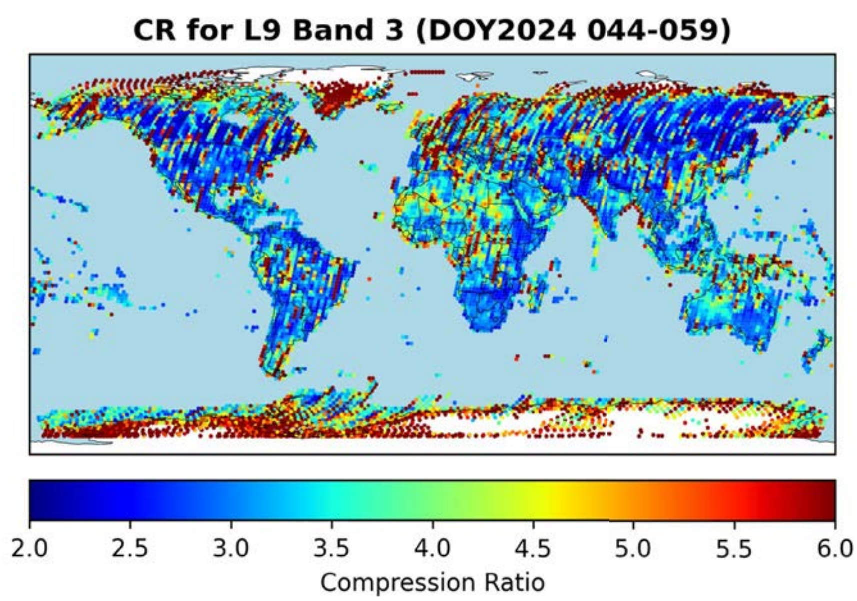


Figure 3: Global compression ratio for Landsat 9 band 3 using the relative error mode.

Estimation of beet yield and leaf spot disease detection using unmanned aerial systems (UAS) sensing.

Sponsor: Love Beets & New York Farm Viability Institute (NYFVI)

Principal Investigator: Jan van Aardt & Sarah Pethybridge (Cornell U.)

Team: Mohammad Shahriar Saif, Rob Chancia, Tim Bauch, Nina Raqueno, Imergen Rosario, Pratibha Sharma (Cornell U.), Sean Patrick Murphy (Cornell U.)

Project Description

The Rochester, NY area is home to a growing economy of table beet root growers and production facilities for various organic beet products, headed by Love Beets USA. Love Beets has been working with the RIT DIRS group and Cornell AgriTech to explore the application of unmanned aerial systems (UAS) remote sensing imagery to beet crop yield estimation, plant count, and root size distribution forecasting. Additionally, we have also been exploring the capabilities of UAS in estimating Cercospora Leaf Spot (CLS) disease severity in table beets. The disease severity at various growth stages of tables beets were assessed during the summers of 2021-2023 by pathologists in Cornell, and the end-of-season harvest yield parameters, root weight, root number, and dry weight foliage also were collected. The goal was to develop models based on the spectral signatures acquired from UAS. This allows farmers to make critical crop management decisions and marks a step towards sustainable and efficient agriculture.

Project Status

Rob Chancia previously published an article in Remote Sensing, reporting on the model developed for 2018 and 2019 season imagery (DIRS annual report for 2022). A total of 13 flights were conducted during the summer of 2021 and 2022, capturing hyperspectral imagery from 400-2500 nm, multispectral imagery, and light detection and ranging (LiDAR) data at different stages of plant growth (see the team in Figure 1). Wavelength indices linked to beet yield prediction were identified, with results from the 2021 data published in 2023 (DIRS annual report for 2023). We next are developing a multi-season yield model which will be submitted for publication end-2024.

However, the main focus for our 2022-2023 analyses was Cercospora Leaf Spot (CLS) disease assessment, using trials conducted between 2021-2023, with the Cornell AgriTech team assessing in-field disease severity. We collected annual imagery (multiple flights/year) using a DJI Mavic 3m to estimate CLS disease severity. We presented our findings at the STRATUS conference held in Syracuse, NY. Figure 2 shows the “operational” CLS disease progression heat map, as generated by our model.

Figure 1. The data collection team during one of the flight campaigns in the summer of 2023.

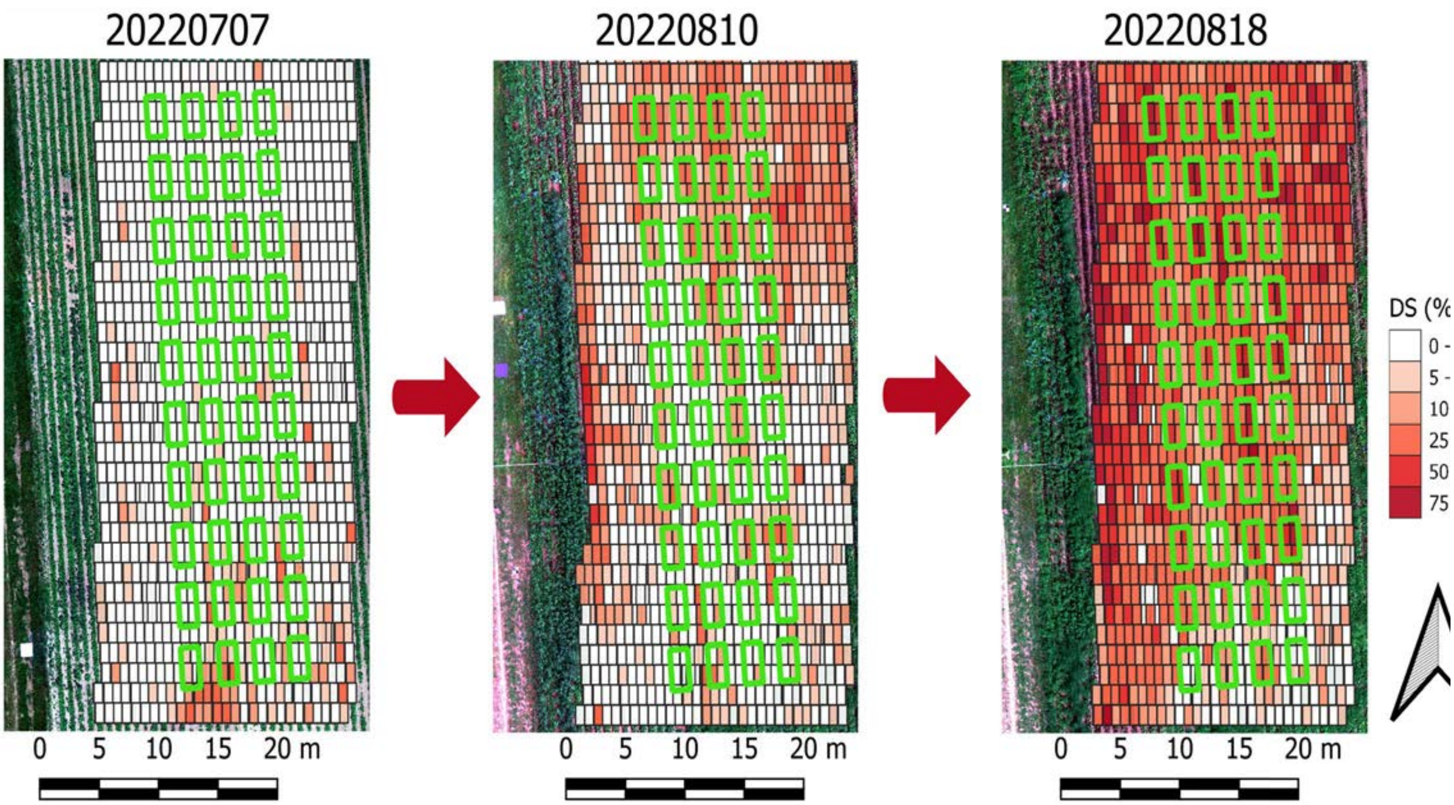


Figure 2. A heat map of estimated DS across the field at three different dates. These maps provide critical insights for growers to make actionable decisions.

On the Use of Terrestrial Laser Scanning for Structural Assessment of Complex Forest Environments

Sponsor: United States Forest Service (USFS)

Principal Investigator: Jan van Aardt

Team: Dr. Rob Chancia, Dr. Richard Mackenzie (USFS), Dr. Ali Rouzbeh Kargar

Project Description

Mangrove forests attempt to maintain their forest floor elevation through root growth, sedimentation, resistance to soil compaction, and peat development in response to sea level rise. Human activities, such as altered hydrology, sedimentation rates, and deforestation, can hinder these natural processes. As a result, there have been increased efforts to monitor surface elevation change in mangrove forests. Terrestrial lidar system (TLS) data were collected from mangrove forests in Micronesia in 2017 and 2019, using the Compact Biomass Lidar (CBL), developed by scientists at the University of Massachusetts (Boston) and RIT. Sediment accretion was assessed using the lidar data, using Cloth Simulation Filtering (CSF), followed by filtering the points based on angular orientation, which improved the performance of the ground detection. The elevation change between the two years was found by subtracting the Z (height) values of the nearest points, detected using a nearest neighbor search. Extreme elevation changes, attributed to human interactions or fallen logs, were removed using interquartile range analysis. The consistency of TLS-measured elevation changes in comparison to the field-measured ones was found to be 72%, with standard error values being 10-70x lower.

Project Status

In March and April of 2024 Jan and Rob traveled to the Republic of Palau in Micronesia to conduct mangrove fieldwork with Richard Mackenzie of the US Forest Service. While in Palau, we obtained surface elevation table (SET) measurements at 17 different SET locations across the island of Babeldaob. The measurements included the traditional pin method, TLS method, and the new iPhone LiDAR method. (see Figure 1 for TLS and Figure 2 for pin). The campaign served as the first mangrove trial of the iPhone LiDAR method, giving us a base dataset to repurpose our TLS processing framework. While conducting our fieldwork we worked with a young Palauan, Skyler Ruben (shortstop for the Angaur Mekaebers of Palau's Major League Baseball), working for the Ministry of Agriculture, Fisheries, and the Environment. Rich, Jan, and Rob trained Skyler in all three methods of SET measurement over the course of the fieldwork campaign so that monitoring of Palau's mangroves resilience to sea level rise will continue.

While in Palau we also engaged in several outreach events with the local community to foster interest in preserving mangrove forests. This included a seminar and LiDAR demonstration featuring Rich, Jan, and Rob at Palau Community College titled “May the force be with the mangroves: Using futuristic technology to monitor Palau's mangroves”. A Palauan student who attended the seminar applied to RIT and will join the project as an Environmental Science MS student starting in the fall of 2024. We presented a similar talk and demonstration to a group of

local women who catch mangroves crabs in the Ngeremlengui state. Another day during our mangrove fieldwork we were accompanied by Miss Palau (2023-2024), a climate ambassador and public figure, to show her the work we are doing to monitor Palau's mangroves (see Figure 2). Finally, we were accompanied by an Island Times journalist, Leilani Reklai, who featured our efforts on the cover of their April 5, 2024 issue (https://islandtimes.org/unveiling-the-power-of-mangroves-new-tech-boosts-carbon-storage-research/, also see Figure 3) by our model.

Figure 1. Skyler and Rob setting up the TLS on a surface elevation table.

Figure 2: Richard MacKenzie shows Miss Palau how to measure the forest floor relative to the surface elevation table using the pin method.

olar energy into the
au Public Utilities (PPUC) announced er kilowatt-hour se in the energy May 1st, 2024. PPUC begins pur- from a new so- operated by an ower Producer

rent total rate kWh, with a cents/kWh nts/kWh for will remain ent increase the energy

anticipat- icity costs of solar contract IPP sets olar en- , higher t. $4 in- sehold onthly, $34 to

Unveiling the Power of Mangroves:

New Tech Boosts Carbon Storage Research

BY: L.N. REKLAI

Palau's Mangroves: A Carbon Powerhouse Under Threat

Mangrove forests are vital ecosystems, acting as nurseries for marine life, reducing coastal erosion, and storing vast amounts of carbon dioxide – a key climate change mitigator. Research in Palau is shedding light on this lesser-known function, with the potential to boost the country's green economy.

However, studying these swampy forests poses challenges. Data collection can be slow and laborious due to the difficult terrain. Additionally, mangrove ecosystems face threats from development projects.

New Tool for Conservation: LiDAR Technology

Recent advancements in Li-

• NEW TECH, 3

Richard MacKenzie, PhD, Mangrove Ecologist & Dr. Jan van Aardt and team from Rochester Institute of Technology applying new technology to mangrove research.

Figure 3: Article featured on the cover of Island Times April 5, 2024.

Analysis of NOx Blast Fumes using Machine Learning, GIS, and Drones

Sponsor: Austin Powder

Principal Investigator: Emmett Ientilucci

Team: Bob Kremens, Nina Raqueno, Xuesong Liu

Project Description

Austin Powder manufactures, distributes, and applies industrial explosives for industries including quarrying, mining, construction, and other applications. Although it's unusual, these massive explosions can release a foreboding yellowish-orange cloud that is often an indicator of nitrogen oxides—commonly abbreviated NOx. Austin Powder is seeking research into the ability to image these plumes so as to estimate concentration (using image processing, machine learning, sensors on drones) and estimate volume. We also seek to automatically identify NOx in the plume itself.

Project Status

We have made field-deployable NOx ground sensors that mount to drones and are currently used by Austin Powder in the field. We have made many in-lab controlled spectral measurements of NOx gas so as to identify absorption features that can be used in algorithms. We have participated in Austin Powder customer blast data collections, created visualizations of NOx concentration and synced video data from UAS's into a spatial environment (GIS) for spatial and temporal analysis. We have deployed our custom NOx sensors at customer sites to measure NOx in units of ppm. We have published papers on an image processing technique to plume segmentation. Our machine learning algorithm, which automatically detects NOx from blast video imagery, is currently be integrated into the Austin Powder blast analysis report. This algorithm will automatically identify the existence of NOx gas from an average of 17,000 blast videos per year.

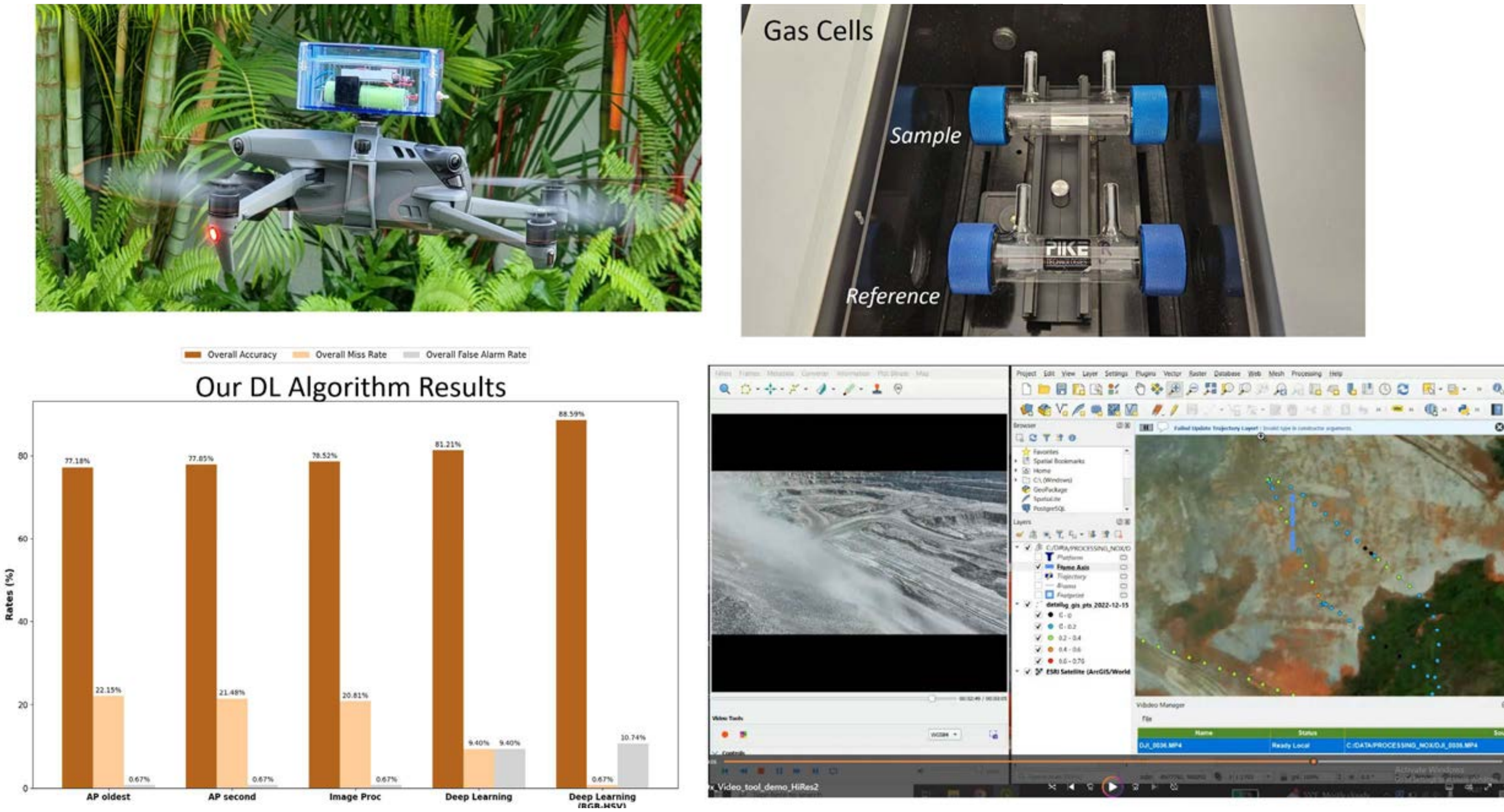


Figure 1 Caption: (top left) One of our custom NOx sensor mounted on an Austin Powder supplied drone being used at a quarry in Panama. (top right) quartz gas cells being used to measure the spectral absorption of NOx gas from the UV to NIR. (bottom left) Overall accuracy, miss rate, and false alarm rate comparing our deep learning NOx detection algorithm, bars on far right, (from video imagery) to existing methods. This was tested on 149 blast videos. (bottom right) Our integration of UAV blast video (w/ our NOx sensor) into a custom QGIS environment utilizing full-motion plug-ins.

Shadow Detection and Mitigation in Satellite Imagery

Sponsor: Oak Ridge National Lab

Principal Investigator: Emmett Ientilucci

Team: Mike Gartley and Tolga Furkan Aktas

Project Description

Shadows are present in a wide range of aerial images from forested scenes to urban environments. The presence of shadows degrades the performance of computer vision algorithms in a diverse set of applications, for example. Therefore, detection and mitigation of shadows is of paramount importance and can significantly improve the performance of computer vision algorithms. This work assumes as input a multispectral image and co-registered cloud shadow maps which are used to calculate shadowed pixel spectral statistics and adjusting to match the statistics of spectrally similar sunlit pixels resulting in a shadow mitigated multispectral image. ORNL also seeks to advance machine learning (ML) approaches to in-paint these cloud shadows.

Project Status

We have developed our image processing approach to shadow mitigation in satellite imagery to the point that it is now ready for publication. In addition, we have demonstrated that shadow mitigation in remote sensing can be addressed through cutting edge deep learning methodologies developed by the computer vision community, contingent upon meticulous data curation. Despite the lack of perfectly paired satellite imagery, our empirical evidence supports the superiority of supervised end-to-end training for shadow mitigation. This approach handles the nonlinearities and nonconvexities in shadow-masked regions, as evidenced by our streamlined experimental benchmark on synthesized datasets.

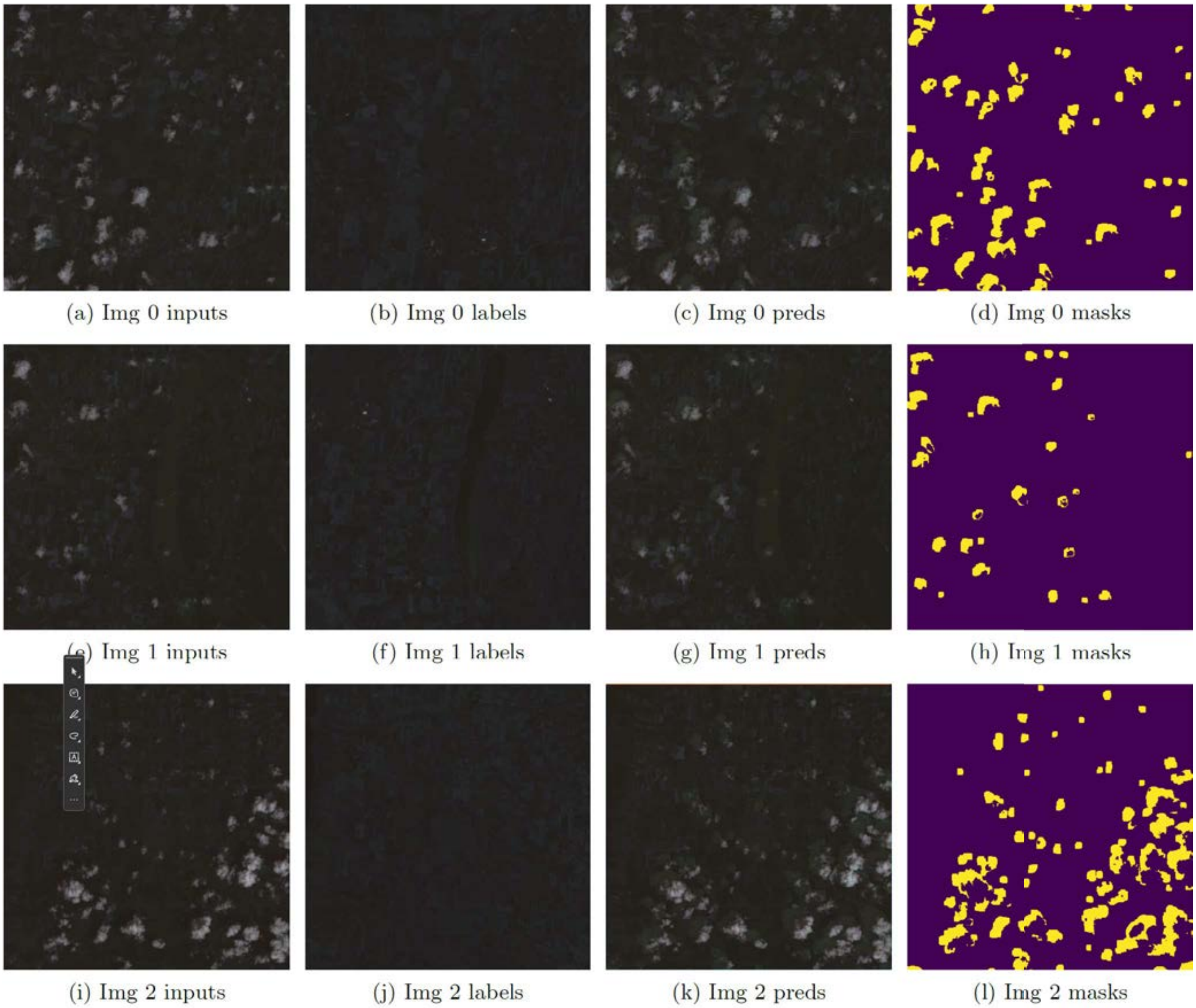


Figure 1. To analyze the generalizability of the model trained on synthetic data, we have provided the trained model with real Landsat 8 input imagery. The Figure demonstrates the qualitative performance on a real-world dataset. We observe that the model attempts to rectify the shadow-contaminated areas by brightening the shadow regions with the guidance of the shadow mask.

Segmenting Smoke Plumes from Background Clutter in Video Imagery using Machine Learning

Sponsor: IEEE Geoscience and Remote Sensing Society (GRSS): ProjNET

Principal Investigator: Emmett Ientilucci and Susmita Ghosh

Team: Xuesong Liu, Abhishek Dey, and Aloke Datta

Project Description

This is a collaborative project between the Western New York IEEE GRSS Chapter and the GRSS Kolkata, India Chapter. It is funded through an initiative called ProjNET which facilitates networking between global GRSS chapters. The objective of this project is to segment smoke plumes in video data (forest fires, burning buildings, blasting, etc.) captured from a remote sensing drone platform and/or ground-level video cameras from surrounding background clutter (i.e., trees, rock, road, etc.). Modern machine learning techniques have been explored for this task.

Project Status

We have developed an innovative method for generating masks from smoke plume images (or video frames), which is capable of distinguishing core regions with dense smoke from confused regions containing thinner smoke plumes and background elements. This is accomplished through a series of morphological operations, detailed in the corresponding figure. Additionally, we have developed a semantic segmentation model where a Random Forest classifier is trained using only the smoke pixels from core regions as ground truth, excluding the unreliable pixels from the confused regions. To enhance classification accuracy, features are extracted using the pre-trained VGG16 network, which significantly reduces the need for a large number of training images and saving computation time. The performance of the proposed model is currently being evaluated against four well-established deep learning models used for semantic segmentation: U-Net, LinkNet, Pyramid Scene Parsing Network, and Feature Pyramid Network. Each of these models utilizes a pre-trained backbone architecture, allowing them to leverage existing knowledge for improved performance. These models, along with their variants, are widely used in various domains, including medical image segmentation, satellite image segmentation, and diverse object detection tasks. A comprehensive qualitative and quantitative analysis of the results will be presented in subsequent reporting. A manuscript detailing the mask generation and segmentation results is being prepared for publication.

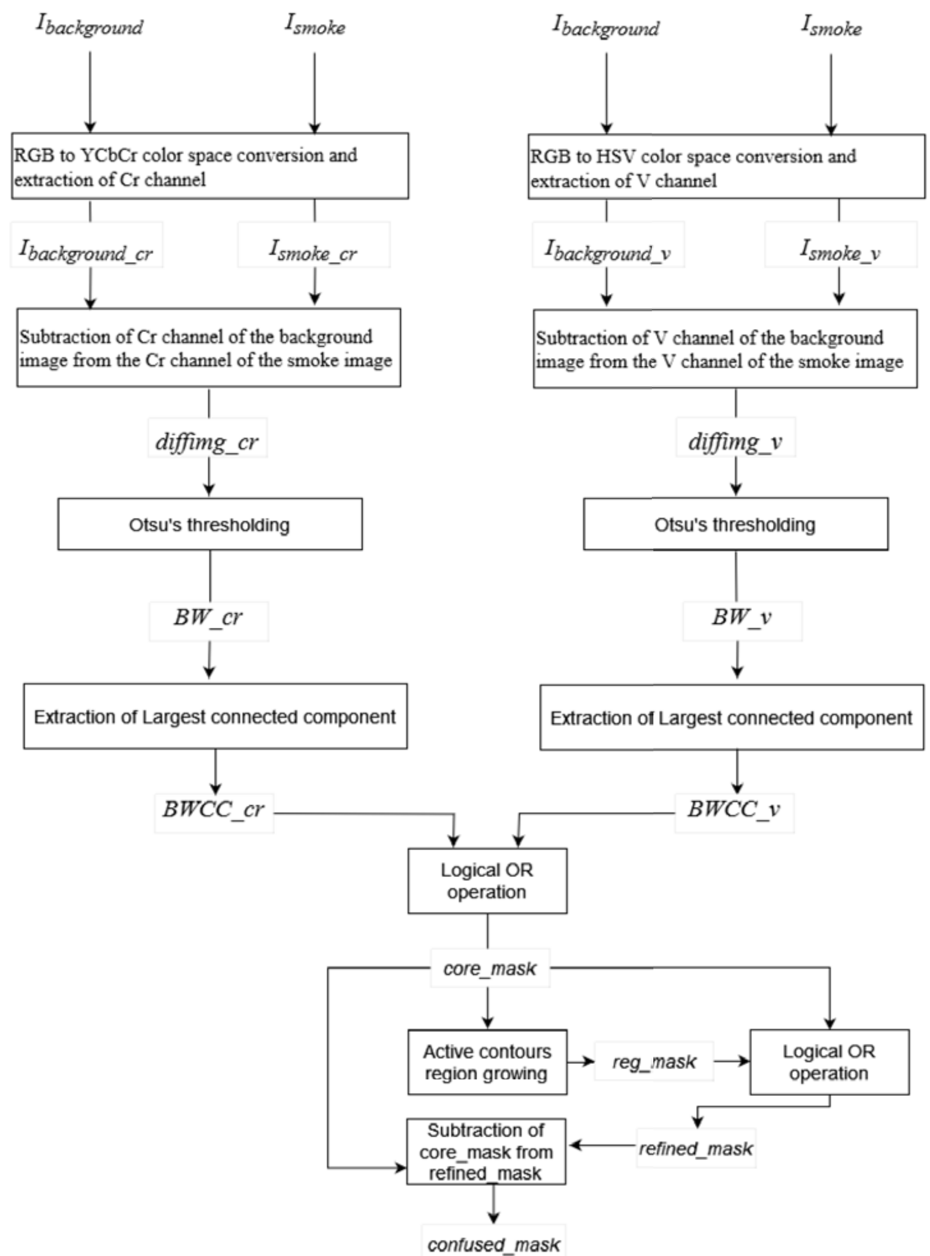


Figure 1. The flowchart above illustrates our new mask generation method called CCReg.

Unexploded Ordinance (UXO) and Landmine Detection using Drones and Multi-modal Imaging

Sponsor: IEEE Geoscience and Remote Sensing Society (GRSS): ProjNET

Principal Investigator: Emmett Ientilucci and Susmita Ghosh

Team: Sagar Lekhak, Susmita Ghosh, Abhishek Dey, and Aloke Datta

Project Description

This is a collaborative project between the Western New York IEEE GRSS Chapter and the GRSS Kolkata, India Chapter. It is funded through an initiative called ProjNET which facilitates networking between global GRSS chapters. The objective of this project is to leverage multimodal drone imagery for the detection and identification of remnants of war (UXO's, landmines, etc.).

It has been noted that explosive ordnances (EOs) have killed or injured 7073 people worldwide in 2020 alone. Recent estimates show that there are more than 100 million pieces of explosive ordnance worldwide unaccounted for. Moreover, the leading cause of civilian casualties in Ukraine, for example, is antivehicle and antipersonnel land mines. In addition to the large amounts of EO still prevalent, it is estimated that, using current technology, removal and clearance of land mines alone could take up to 1100 years. This is clearly unacceptable. The issue will soon manifest itself when the Ukraine war draws to a close.

Accordingly, electromagnetic induction (EMI) technology (e.g., handheld EMI metal detectors) is currently the standard geophysical methodology that humanitarian mine action (HMA) survey operators rely on to detect subsurface EOs. Clearly this is a slow and laborious process. Unmanned aerial vehicles (UAVs) offer a much faster and safer solution to the problem of detection and identification of EOs over large swaths of land. UXOs can be buried in deep grass and are often hard to detect. In this project, we aim to combine multimodal (i.e., hyperspectral (VNIR and SWIR), Lidar, thermal, and/or SAR, etc) UAV data and imaging capabilities with state-of-the-art algorithm development to illustrate "faster" and more effective means of detection and identification of such remnants of war.

Project Status

To date, we have attended the Geneva International Centre for Humanitarian Demining (GICHD) meeting in Geneva, Switzerland so as to learn about the state of humanitarian deming around the world. The GICHD is a non-profit organization, based in Switzerland, that works to reduce the risk of explosive ordnance to communities. The GICHD's focus is on landmines, cluster munitions, explosive remnants of war, and ammunition stockpiles. The organization's goal is to help develop and professionalize the sector for the benefit of its partners, which include national and local authorities, donors, the United Nations, and non-governmental organizations. We also know that actual UXO objects can be very difficult, if not impossible, to obtain and measure. Thus, we plan to work with the Center for Fire and Explosives, Forensic Investigation, Training and Research (CENFEX) at Oklahoma State. This facility has dozens of UXO objects permanently deployed in a test field specifically for research related to the goal of helping research understand the remnants of war problem. Moving forward will visit the site, collect data, write papers on what the data tells us and search for a source of funding to support an RIT PhD student.

Figure 1: (Top) Photo from the GICHD global humanitarian demining meeting in Geneva, Switzerland. The yellow circle shows the location of PI Emmett Ientilucci. (Bottom) Condensed grid for visualization of placement of each UXO/Landmine item at the CENFEX (Oklahoma State) seeded test field. Objects were scattered (in a known manner) throughout a large area. Some were buried at known depths while others were left on the surface. A small sampling of objects includes M6A1 and M83 rockets, pipe bombs, M228 frag and M18 grenades, riot grenades, PFM-1 landmines, shell casing, IED's, various submunitions, anti-personnel mines, and various clutter to act as confusers.

HiRes Vineyard Nutrition

Sponsor: United States Department of Agriculture (USDA)

Principal Investigator: Jan van Aardt

Team: Dr. Rob Chancia, Tim Bauch, Nina Raqueno, Mohammad Shahriar Saif, Dr. Terry Bates (Cornell U.), Dr. Justine Vanden Heuvel (Cornell U.), Manushi Trivedi (Cornell U.)

Project Description

The USA annual grape production value exceeds $6 billion across as many as 1 million acres (>400,000 ha). Grapevines require both macro- and micro-nutrients for growth and fruit production. However, inappropriate application of fertilizers to meet these nutrient requirements could result in widespread eutrophication through excessive nitrogen and phosphorous runoff, while inadequate fertilization could lead to reduced grape quantity and quality. It is in this optimization context that unmanned aerial systems (UAS) have come to the fore as an efficient method to acquire and map field-level data for precision nutrient applications. We are working in coordination with viticulture and imaging teams across the country to develop new vineyard nutrition guidelines, sensor technology, and tools that will empower grape growers to make timely, data-driven management decisions that consider inherent vineyard variability and are tailored to the intended end-use of the grapes. Our primary goal on the sensors and engineering team is to develop non-destructive, near-real-time tools to measure grapevine nutrient status in vineyards. The RIT drone team is capturing hyper and multispectral imagery over both Concord (juice/jelly) and multiple wine variety vineyards in upstate New York.

Project Status

Over the course of four growing seasons, we have gathered imaging data of grapevines from multiple platforms and modalities coincident with nearly 2000 ground truth nutrition samples. Most imaging data was captured in coordination with field leaf and petiole sampling studies, conducted by Dr. Terry Bates in concord grape vineyards at the Cornell Lake Erie Extension Laboratory (CLEREL). This has resulted in models capable of predicting concentrations of macronutrients, like nitrogen, phosphorous, and potassium, using spectral imagery. In the spring of 2024, the team at CLEREL executed their first variable-rate fertilization based on predictions from the RIT team using the cloud-based GIS application myEfficientVineyard (myEV tool: my.efficientvineyard.com). The variable-rate fertilizer spreader shown in Figure 1 is guided by the prescription map pictured in Figure 2, to test vineyard response to precision fertilization.

The spring of 2024 also included several presentations and outreach events. We presented a talk titled “A comparison of VNIR range sensors for assessing canopy variability in vineyards”, at the 2024 IEEE Systems and Technologies for Remote Sensing Applications Through Unmanned Aerial Systems (STRATUS) conference in Syracuse, NY on May 22nd. We presented about the HiRes Vineyard Nutrition (HRVN) project and conducted a drone flight demo at the Precision & Digital Viticulture Field Day at CLEREL on June 6th, exposing the project and sensor technology to some ~50+ local concord grape growers (see Figure 3). Rob Chancia furthermore was a panelist along with Terry Bates in a discussion of vine nutrition for the American Society for Enology and Viticulture Eastern Section “Hang Time” virtual panel on June 13th. Finally, Rob met with Patty Skinkis to record an episode for the HRVN podcast on June 21st.

We gathered drone data at two Concord study blocks at CLEREL on June 18, 2024, in coordination with Terry Bates’s (Cornell University) sampling plan and the earlier-mentioned variable rate nutrition experiment. We also purchased and potted three Concord vines from Double A Vineyards to grow at RIT for a lab experiment to determine the bidirectional reflectance distribution function (BRDF) of grapevine leaves with an imaging goniometer later in 2024. The resulting BRDF will be a useful input to radiative transfer models developed by the HRVN sensors and engineering team.

Figure 1. Lanco variable-rate fertilizer spreader in action.

Figure 2. Variable-rate prescription map in an AgLeader field computer.

Figure 3. Drone demonstration group photo from the Precision & Digital Viticulture Field Day at Cornell Lake Erie Research and Extension Laboratory.

PASET TEAL

Sponsor: Partnership for Skills in Applied Sciences, Engineering and Technology

Principal Investigator: Anthony Vodacek

External Collaborators: Gerard Rushingabigwi (PI) and Louis Sibomana (Co-PI), University of Rwanda

Project Description

Tools for East African Lakes (TEAL). The aim of this project is to assemble and test a relatively inexpensive set of devices to support the creation of Internet of Things sensor networks for measuring optical properties and temperatures of East African lakes. Successful creation and practical deployment of these types of sensor networks at scale, and the satellite remote sensing measurements they enable, will improve the knowledge of lake managers about lake conditions in East Africa. This project also aligns with the goals of the African Center for Aquatic Research and Education (ACARE) lake monitoring committee, of which Dr. Vodacek is a member.

Project Status

The prototype system is operating and collecting spectra, with the Hamamatsu mini-spectrometer providing 14-bit data using the Arduino Minima. Upcoming work will include calibration of one of the sensors using the DIRS calibration lab to determine relative spectral response for all channels and radiance and irradiance calibration. Other specific development includes building the collection hardware for using the sky-blocked remote sensing reflectance method.

Figure 1: Two views of the prototype for measuring water remote sensing reflectance. Left – The packaged system showing the detail of the fiber optic connector attached to the Hamamatsu mini-spectrometer, with rechargeable batteries and GSM module on the bottom. Right – Packaged system showing the two fiber connectors for the two required measurements, and the GSM module.

PASET ADAM

Sponsor: Partnership for Skills in Applied Sciences, Engineering and Technology

Principal Investigator: Anthony Vodacek

External Collaborator: Emmanuel Ndashimye (PI), Damien Hanyurwimfura (Co-PI), University of Rwanda

Project Description

Agricultural Data from Acoustic Monitoring (ADAM). The aim of this project is to investigate the use of passive acoustic sensors for monitoring agricultural phenomena and activities that produce sound. Some examples of phenomena and activities related to agricultural production that have an associated sound include farm animals, rain, plants moving in the wind, flowing water, machinery, people, and pest animals, insects, and birds. All of these processes can impact agricultural production and value-added activities over the 24 hours of the day and across the whole area of a farm. Farmers do not have the ability to monitor all these processes in person, but a low-cost network of acoustic sensors might give the farmer the ability to collect and analyze sound information about their farm, even when no one is there to hear.

Project Status

T his project has two parts. The first is to create an Internet of Things prototype system for detecting known pest birds which eat ripening crops based on their calls, and then taking an action to scare the birds away, such as making a loud sound. To keep the cost minimal, Arduino compatible devices with an acoustic sensor, a module capable of running a compact machine learning algorithm on the data, and the ability to send a text message, are used. Work is ongoing for powering with solar charged batteries, and creating a network of sensors rather than standalone sensors. The second research direction is to develop the compact algorithms for classifying sounds at the edge, e.g., in an environment with low computational resources. This includes investigating the most effective feature extraction methods and the testing of a number of models, including the use of knowledge distillation and existing small models. While still under investigation, very good accuracies and precision have been found for models requiring only a few MB of memory for deployment.

Figure 1: Prototype system for field deployment. This system uses Arduino compatible parts, including the acoustic sensor, GPS for accurate timing, the ability to apply compact machine learning models on the data, and GSM service to send an SMS alarm.

Models	Accuracy	Recall	Precision	F1_score	Specificity	Model size
Distilled EfficientNetB0	0.9829±0.0226	0.9880± 0.0104	0.9781 ±0.0186	0.9830 ±0.0116	0.9922 ±0.0092	22.9 MB
EfficientNetB0	0.7342±0.0178	0.7554± 0.0407	0.7427 ±0.0302	0.7489± 0.0433	0.7968 ±0.0283	22.9 MB
EfficientNetB4	0.9930±0.0071	0.9937± 0.0062	0.9918± 0.0106	0.9927± 0.0065	0.9938 ±0.0048	330MB
MobileNetV1	0.5265±0.0157	0.5120 ±0.0332	0.5895 ±0.0312	0.5480 ±0.0361	0.4940 ±0.0231	37.2MB
MobileNetV2	0.9872±0.0105	0.9759 ±0.0236	0.9914 ±0.0125	0.9835 ±0.0118	0.9906 ±0.0110	28.2 MB
Distilled GRU	0.8688±0.0202	0.8913 ±0.0226	0.8634 ±0.0077	0.8771 ±0.0189	0.8630±0.0082	196.8 KB
GRU	0.8419±0.0162	0.8497 ±0.0137	0.8577 ±0.0095	0.8536 ±0.0116	0.8520±0.0166	196.8 KB
LSTM	0.8850±0.0117	0.9339 ±0.0176	0.8861 ±0.0201	0.9093 ±0.0211	0.8738±0.0217	29.8 MB
LightGBM	0.9874±0.0063	0.9904 ±0.0067	0.9750 ±0.0154	0.9826 ±0.0085	0.9854±0.0166	0.047 KB
SVM	0.9764±0.0119	0.9791 ±0.0127	0.9655 ±0.0163	0.9722 ±0.0095	0.9667±0.0199	3.3MB

Figure 2: Table comparing various performance metrics for a number of machine learning approaches for processing acoustic data. Useful models for IoT deployment require a balance of good performance and small model size.

People

The following represents and describes each of our talented list of faculty members, staff, and students. The time and effort from our members allows for the team to be sucessful in our research.

Faculty & Staff

Carl Salvaggio

Director of the Digital Imaging and Remote Sensing Laboratory and Full Professor of Imaging Science, Carl received his Bachelors and Masters degrees in Imaging Science from the Rochester Institute of Technology in 1987 and his Ph.D. in Environmental Resource Engineering from the SUNY College of Environmental Science and Forestry in 1994. Carl teaches and conducts research in image processing, computer vision, remote sensing, and programming. His research interests address the development of solutions to applied, real-world, problems utilizing the appropriate imaging modalities and algorithmic approaches. Carl's expertise are in thermal infrared phenomenology, exploitation, and simulation; design and implementation of novel imaging and ground-based measurement systems; three-dimensional geometry extraction from multi-view imagery; material optical properties measurement and modeling; radiometric and geometric calibration of imaging systems; and still and motion image processing for various applications.

Joesph Sirianni

Associate Director of the Digital Imaging and Remote Sensing Laboratory, Joe received his Bachelors (1992) and Masters (1994) degrees in Imaging Science from the Rochester Institute of Technology. During his 25-year career in the aerospace and defense industry Joe conducted research in image processing algorithms, software development and remote sensing and was a program and business development manager. Joe's continued interest in all-things imaging science, remote sensing and business development drive is a perfect combination for his current role with responsibilities in program management and business development for discovering new sponsored research opportunities for graduate students and research staff.

Jamie Albano

AJames received his B.S. (2008) and Ph.D. (2014) degrees in Imaging Science from Rochester Institute of Technology. After graduate school, James spent time working in air and missile defense at several locations including MIT Lincoln Laboratory, General Dynamics Mission Systems, and BAE Systems where he primarily focused on the development of advanced radar signal processing algorithms for detection, tracking and identification of air- and space-borne threats. In 2022, he took a position at the Digital Imaging and Remote Sensing Laboratory as a Research Scientist where he is currently researching several areas of radar signal processing including synthetic aperture radar (SAR) image formation processing, SAR automatic target recognition (ATR), moving target indication (MTI), space-time adaptive processing (STAP), multistatic radar signal processing, and multimodal sensor fusion. He currently teaches a special topics course on SAR image formation processing that is offered in the Fall semester.

Chip Bachmann

He received the A.B. degree in Physics from Princeton University, in 1984, and the Sc.M. and Ph.D. degrees in Physics from Brown University in 1986 and 1990, respectively. After a 23-year career at the U.S. Naval Research Laboratory in Washington, DC, Chip joined the RIT Chester F. Carlson Center for Imaging Science faculty as the Frederick and Anna B. Wiedman Chair. Since 2016, he has also served as CIS Graduate Program Coordinator. He holds two U.S. Patents for methods of analysis related to hyperspectral remote sensing imagery. His research interests include hyperspectral and multi-sensor remote sensing applications in coastal and desert environments, BRDF and radiative transfer modeling for retrieval of geophysical and biophysical parameters, field calibration and validation, and the development of advanced instrumentation (goniometers and more recently a mast-mounted hyperspectral video system), as well as abstract models for interpreting hyperspectral and multi-sensor imagery based on manifold descriptions and graph theory.

Tim Bauch

Research Engineer I and sUAS Pilot for the Digital Imaging and Remote Sensing Laboratory, Tim received his Associates degree in Optical Systems Technology from Monroe Community College in 2015 and his Bachelors degree in Imaging Science from Rochester Institute of Technology in 2017. Tim received his Part 107 FAA Pilots license for sUAS Commercial Operations in January 2018. He has performed over 600 flights since that time for many different research projects. His research interests involve using drone technology to solve real world problems to areas such as precision agriculture, infrastructure, environmental science and remote sensing algorithm development. In addition, he has interests in system integration and design for both ground based and UAS Imaging systems. Tim also loves to help and instruct students and is teaching the Freshman Imaging Project in the Chester F. Carlson Center for Imaging Science.

Brian Benner

Coordinator of Admin Lab Operations, Brian received his Bachelor's degree in Mechanical Engineering from Rochester Institute of Technology in 2014. After spending some time in industry, he joined the Chester F. Carlson Center for Imaging Science last year, helping with facilities management, lab safety, swipe/key access, and managing the department's stock room. He received his Part 107 FAA Pilots license for sUAS Commercial Operations in July 2023 and will be starting graduate level courses in the fall.

Karen Braun

Karen is the Associate Director for the Center for Imaging Science, where she received her PhD in 1996. In the meantime, she was a color scientist and area manager at Xerox for 20 years, volunteering with the Xerox Science Consultant Program, FIRST Lego League, and United Way Day of Caring. She received the Rochester Business Journal's Forty Under 40 award. Karen has also received the Golden Brick Award, and the Guiding Star Award.

Scott Brown

Head of the Modeling and Simulation group within the Digital Imaging and Remote Sensing Lab. This group focuses on the modeling of airborne and space-based passive and active EO/IR imaging systems. Scott's specific expertise is the mentoring of student and staff re-search projects and the implementation and integration of complex radiation propagation codes. Since 1994, he has been the lead for the physics-driven image and data simulation model called DIRSIG. This model is elaborate software architecture for radiation propagation across the EO/IR region. The capabilities of the model range from passive temperature calculations to active time-gated, LIDAR predictions. The model consists of nearly a million lines of C++ and is externally distributed to government organizations and contractors. Scott routinely conducts on- and off-site training courses that are attended by the professional community regarding the use of the remote sensing modeling and simulation tools developed at RIT and general remote sensing system design and phenomenology.

Byron Eng

As a member of the DIRSIG team, Byron helps train and mentor new DIRSIG users. Byron joined the Digital Imaging and Remote Sensing Laboratory as an Assistant Research Scientist in 2019. He earned a Master's degree in Mechanical Engineering from the University of Utah, where he specialized in Heat Transfer, Atmospheric Sciences, and Fluid Mechanics. As the subject matter expert in heat transfer, Byron helps refine the methods in which temperature predictions are made for DIRSIG simulations of thermal imaging systems. Byron is interested in applying his expertise in research topics such as renewable energy, air quality, and atmospheric modeling.

Jeff Dank

Jeff joined the Digital Imaging and Remote Sensing Laboratory as a Research Enginerr II in August 2021. He earned a Master's in Business Administration and Bachelor's degree in Imaging Science from The Rochester Institute of Technology, as well as a Bachelor's degree in Applied Computer Science from CU Boulder. He has 16 years of experience as a Research Scientist / Systems Engineering and Technical Advisor for both Lockheed Martin and Integrity Applications Incorporated. He is interested in real time rendering of synthetic images and sharing his experience with students and customers to enable them to be DIRSIG power users.

Laua Girolamo

CIS Senior Analyst

Serena Flint

Serena joined the Digital Imaging and Remote Sensing Laboratory as a Researcher/Engineer I in late June 2022. She earned a Bachelor's degree in Physics and Astronomy earlier this year from the University of Rochester. For the past three years, her research focused on using machine learning to mimic spectropolarimetric inversions in solar physics. Now, she is excited to learn more about the world of imaging science and looks forward to opportunities to work on various projects in the future.

Jacob Irizarry

Joining the DIRSIG team in late 2021, now a Research Engineer/Support Jacob work's as the expert on 3d asset creation. Currently pursuing a Master in Business Administration, and having earned a Bachelor's degree from RIT in 3D Digital Design. I graduated early under the class of 2022, I used my time from graduating early to work on developing a new IP in the 3D world, in addition to continuing work as a contractor for the DIRSIG labs to create custom 3d assets, before formally joining the DIRSIG team as a full time member in August of 2022. I'm excited to learn more about the sciences and, I'm ecstatic that I have been able to bring my expertise in the world of art and design to Imaging Science and connect the two worlds.

Michael Gartley

Assistant Research Professor in the Center for Imaging Science. Michael received his Bachelors degree in Physics from Binghamton University in 1995, his Masters degree in Materials Science and Engineering from Rochester Institute of Technology in 1997 and his PhD in Imaging Science from Rochester Institute of Technology in 2007. He teaches multiple graduate level courses, one of which he developed to teach practical approaches to system level design trades he learned from his 10 years in industry prior to entering academia. His research often focuses heavily on low level modeling and simulation of various remote sensing modalities such as panchromatic, polarimetric, spectral, and Synthetic Aperture Radar. Michael is also conducting research to improve detection, characterization and monitoring of resident space objects for improved Space Situational Awareness.

Aaron Gerace

Assistant Research Faculty in the Chester F. Carlson Center for Imaging Science. Aaron completed his Bachelors and Masters degree in Mathematics from Brockport College in 2002 and his Ph.D. in Imaging Science from the Rochester Institute of Technology in 2010. His research in the Digital Imaging and Remote Sensing laboratory focuses on calibration of spaceborne thermal sensors and validation of their corresponding higher level products. An upcoming award will enable him to investigate the impact of future Landsat sensor designs on science applications. He is motivated by challenging problems and the wise words of RATM.

Adam Goodenough

Research Engineer II with the Digital Imaging and Remote Sensing Laboratory and co-developer of the Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool. Adam received his B.S. and Ph.D. degrees in Imaging Science from the Rochester Institute of Technology (RIT) in 2001 and 2007, respectively. His contributions to the remote sensing community were recently recognized with the 2017 USGIF Achievement Award in Academia. His research interests include modeling and simulation, water quality monitoring, and data visualization.

Amir Hassanzadeh

Amir Hassanzadeh is a Research Engineer II at the center for imaging science. Amir completed his undergraduate studies in engineering at the University of Guilan, Iran, before pursuing a Ph.D. in Imaging Science at the Rochester Institute of Technology (RIT). During his doctoral research, Amir's focus was on yield modeling and harvest scheduling of broad-acre crops, employing drone-based hyperspectral sensing. Amir's broad research interests span across precision agriculture, satellite and drone-based imaging, thermal sensing, machine learning, deep learning, and optimization techniques. research is about investigating new field calibration targets (i.e., convex mirrors) to assess the radiometric and spatial response of hyperspectral/multispectral imaging systems.

Emmett Ientilucci

Gerald W. Harris Endowed Professor and Graduate Admissions Chair in the Chester F. Carlson Center for Imaging Science. Dr. Ientilucci has degrees in optics and imaging science. He is the recipient of the 2020-21 Eisenhart Provost's Award for Excellence in Teaching at RIT. His research interests include, spectral image analysis and variability, hyperspectral image processing, target and shadow detection, radiometric calibration, humanitarian demining, atmospheric compensation and algorithm development. He has 95 publications and has served as referee on 18 journals including being an Associate Editor for a special issue of Optical Engineering (OE) and current Associate Editor for Geoscience Remote Sensing Letters (GRSL). He has been a program reviewer for NASA, the Department of Defense, and is Chair for the SPIE Imaging Spectrometry Conference, the WNY Geoscience and Remote Sensing Society, and the UAS STRATUS Conference. He is a member of the International Society of Explosives Engineers (ISEE), Optical Society of America (Optica), and Senior member of both the Institute of Electrical and Electronics Engineers (IEEE) and Society of Photo-Optical Instrumentation Engineers (SPIE). He is also a member of the international honor society of IEEE-HKN.

Lori Hyde

Lori joined the Chester F. Carlson Center for Imaging Science in December 2021. She earned a Master's in Higher Education from the University of Rochester. Lori pursued research and internships in academic advising and career counseling. While there, Lori joined the staff of RIT's College of Science in 2016 as a scheduling officer and Senior Staff Assistant with Thomas H. Gosnell School of Life Science. Currently, Lori assists the Graduate Program Coordinator and the CIS Director with the administration of the Imaging Science M.S. and Ph.D. programs, including course scheduling, student enrollments, and tracking student progress toward graduation.

Colleen McMahon

Research Program Coordinator for the Digital Imaging and Remote Sensing Laboratory, with 10 years of experience in an administrative role, Colleen keeps our lab running with support in grant management, budgets, and logistics, to name a few. Colleen is pursuing a degree in Business Administration from Rochester Institute of Technology. When she is not putting up with our team's shenanigans, Colleen is an active member of the Seneca Siberian Husky Club.

John Kerekes

Research Professor of Imaging Science. John received his BS, MS, and Ph.D. in Electrical Engineering from Purdue University in 1983, 1986, and 1989, respectively. His research interests include remote sensing system analyses and performance sensitivity studies using simulation and modeling techniques. While his primary expertise is in the area of hyperspectral imaging systems, he has also worked with other remote sensing modalities including thermal imaging, lidar and synthetic aperture radar, with applications ranging from object detection and land cover classification to atmospheric sounding. John is also an active volunteer with the IEEE Geoscience and Remote Sensing Society. Prior to joining RIT, he was a staff member at the MIT Lincoln Laboratory for 15 years.

Robert Kremens

Dr. Kremens is an atomic physicist by education but has spent most of his career as an instrument physicist designer. In addition to a BS, MS and PhD in physics, he obtained a mid-career MS in Environmental Science. He has a strong history of designing and implementing complex experimental apparatus in government, industrial and academic settings. Bob has broad knowledge in measurement techniques including electronics design and fabrication, transducer interfacing, data acquisition and reduction, optical systems, lasers, pulsed power systems, vacuum systems and mechanical assemblies. Recently he has been engaged in designing and deploying portable, inexpensive, fireproof energy flux measurement for observation of wildland fires. Some of this unique equipment includes multi-pleband infrared radiometers, convective flow gauges that operate in high temperature environments, wide dynamic range data acquisition electronics and multiple band in fire camera systems. He has successfully deployed these sensors hundreds of times in the harsh environment of wildland fire.

David Messinger

Dr. Messinger received a BS in Physics from Clarkson University and a Ph.D. in Physics from Rensselaer Polytechnic Institute. He is currently a Professor and the Xerox Chair in Imaging Science at the Rochester Institute of Technology, having served as the Director of the Center for Imaging Science from 2014-2022. He is a Fellow of SPIE and has published over 180 scholarly articles. His research focuses on projects related to image system analysis and spectral image processing using advanced mathematical approaches with applications to remote sensing and cultural heritage imaging.

Patricia Lamb

Senior Staff Assistant for the Chester F. Carlson Center of Imaging and Science since 2018. Prior to coming to RIT, she worked for one of the world's largest distributors of electronic components and embedded solutions. With 30 years of experience in an administrative role at a corporate level. Patty supports faculty, staff, students and post-doctoral researchers. Patty's husband is a proud alumnus of RIT.

Daniel Kaputa

Director of Ravven Labs and Assistant Professor of Computer Engineering Technology, Dan received his Bachelors degree in Computer Engineering [2002] and Masters [2004] and PhD [2007] in Electrical Engineering from the State University of New York at Buffalo. Dan teaches and conducts research in FPGA programming, image processing, computer vision, deep learning, and UAVs. His research interests are broken into two distinct categories namely FPGA based on board video processing for GPS denied navigation and object classification and localization via quantized neural networks. His passion is to combine both domains to create a single FPGA based UAV capable of real time object detection for counter UAS applications.

Matthew Montanaro

Matt holds degrees in Physics (BS, 2005) and Imaging Science (PhD, 2009) and is currently a Senior Research Scientist involved in the calibration of imaging instruments through NASA Goddard Space Flight Center. He specialized in the calibration and characterization of many NASA flight instruments including the Landsat 8/Thermal Infrared Sensor (TIRS), the Landsat 9/TIRS-2, the Lucy/Ralph, the New Horizons/Ralph, and the Solaris pathfinder instrument. He is directly involved in the definition of the calibration methodologies, execution of characterization tests, and analyses of instrument performance data, both pre-flight and on orbit. He is currently supporting the upcoming Landsat Next mission with NASA and the US Geological Survey (USGS). Matt has a number of peer-reviewed scientific journal publications and conference proceedings and has presented at various remote sensing-related conferences. Additionally, he has supported and advised a number of graduate and undergraduate students.

Marci Sanders

Marci Sanders received a Bachelors Degree from RIT in 2020 and is pursuing her Masters in Higher Education form the University of Rochester. Marci Sanders is the student financial assistant, responsible for processing student employment, tuition remission, and stipend payment paperwork. She supports over 100 undergraduate and graduate students. Making sure our students have money for rent and groceries is her top priority.

Nina Raqueño

Research Engineer for the Laboratory for the past 20 years. Nina received a Bachelors in Imaging Science from the Rochester Institute of Technology in the 1990s. Nina escaped for several years to SUNY College of Environmental Science and Forestry where she learned practical remote sensing tools, such as GIS, GPS, surveying, flight planning, and many of the skills required for field work. Nina also served as a technical illustrator for "Remote Sensing: The Image Chain Approach". She was eventually lured back to RIT and DIRS by Dr. John Schott with the promise of spending cloud free days on Lake Ontario (which, by the way, is not quite the ocean but at least it's wet). The first project she was assigned to was Landsat 7 thermal calibration which she continues today as part of NASA/USGS's Landsat Calibration Team. Nina continues to coordinate remote sensing field campaigns of all sizes and for a variety of platforms, satellite, aircraft, rooftop, and now from sUAS. Basically, the only thing that has changed in 20 years is now with the advent of sUAS we can fly more often and under those pesky clouds.

Michael Grady Saunders

Grady is a member of the Modeling and Simulation team in the Digital Imaging and Remote Sensing Lab. He received his Bachelor's degree with honors from East Tennessee State University in 2017, where he majored in Digital Media and minored in Mathematics. He earned a Master's in Imaging Science here at RIT in 2020. Following his graduation, Grady was happy to join the department as an Assistant Research Scientist. His primary role on the Modeling and Simulation team concerns the creation and management of high fidelity virtual environments to serve as inputs to the 5th edition of the Digital Imaging and Remote Sensing Image Generation model, or DIRSIG5. His scientific interests, revolve around stochastic light-transport simulation and procedural modeling techniques in the context of 3D computer graphics and computer generated environments. Prior to the pandemic, he also frequented nearby trampoline parks to hone his flipping skills.

Amanda Zeluff

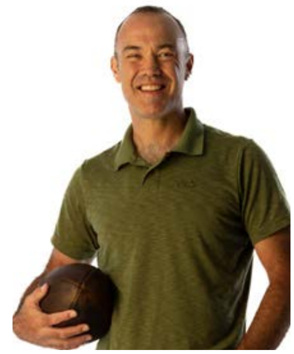
Amanda Zeluff works for RIT's Sponsored Programs Accounting as a Sr. Staff Accountant. She administers financial aspects of externally funded grants and contract for the Center for Imaging Science. She provides post-award management and direct support to the Principal Investigators. Amanda is a Summa Cum Laude RIT alumni with her BS in Business administration. She has worked for RIT since 2011 and has held several positions on campus. Her favorite aspect to her position is the complexity of the Federal Uniform Guidance/FAR and keeping all the DIRS PI's in line with the policies and procedures of grant and contract management.

Eon Rehman

Rehman Eon received a BSc. from Viterbo University in Mathematical Physics and Chemistry, and his Ph.D. in Imaging Science from the Rochester Institute of Technology (RIT). His research interests include the use of optical remote sensing for the assessment of earth sediments and vegetation, radiative transfer modeling, thermal calibration of air/space-borne imaging sensors, development of surface temperature algorithms, and defining requirements for future Earth Observing systems.

Jan van Aardt

Full Professor in the Chester F. Carlson Center for Imaging Science. Jan obtained a B.Sc. Forestry degree ("how to grow and cut down trees") from the University of Stellenbosch, South Africa in 1996. He completed M.S. and Ph.D. Forestry degrees, focused on remote sensing (imaging spectroscopy and light detection and ranging), at the Virginia Polytechnic Institute and State University, Blacksburg, Virginia in 2000 and 2004, respectively. This was followed by post-doctoral work at the Katholieke Universiteit Leuven, Belgium, and a stint as research group leader at the Council for Scientific and Industrial Research, South Africa. Imaging spectroscopy and structural (lidar) sensing of natural resources form the core of his efforts, which vary between vegetation structural and system state (physiology) assessment. Or stated differently, the interaction between photons and leaves is what really gets him going. He has received funding from NSF, NASA, Google, and USDA, among others; Jan and his students also have published >90 peer-reviewed papers and >100 conference contributions.



Anthony Vodacek

Full Professor of Imaging Science. Vodacek received his B.S. (Chemistry) in 1981 from the University of Wisconsin Madison and his M.S. and Ph.D. (Environmental Engineering) in 1985 and 1990 from Cornell University. His areas of research lie broadly in multi-modal environmental remote sensing with a focus on the coupling of imaging with environmental modeling for application to monitoring both terrestrial and aquatic systems. He has specific expertise in spectral phenomenology, image interpretation, aquatic optics, and wildland fire monitoring and he has recently begun working with passive acoustic networks for sensing of the environment. He has international collaborations in several African countries, where he has worked on various teaching and research projects for over ten years. Vodacek is an Associate Editor for the Journal of Great Lakes Research, is a Senior Member of IEEE, and supports the IEEE Geoscience and Remote Sensing Society Global Activities Directorate as the regional liaison to Africa.

Melanie Warren

Since 2010, a Senior Staff Assistant for the Digital Imaging and Remote Sensing (DIRS) and the Multidisciplinary Vision Research (MVRL) Laboratories. Melanie received her Bachelor's in criminal justice from Niagara University. Including a semester of study abroad at the University of Copenhagen. Melanie enthusiastically supports faculty, staff, and students with procurement purchases, travel arrangements, processing of reimbursements, lab support, special event coordination, and hospitality. She has served on the committee and chaired the College of Science Staff Advisory Council, COSSAC. Go Tigers! As always Go Bills!

Post-Doctoral Researcher

Rob Chancia

Rob is currently a Post Doctoral Researcher at the Center for Imaging Science. He received his PhD in Physics from the University of Idaho in 2019, for his work with outer planet imagery from NASA's Cassini, Voyager 2, and New Horizons spacecraft. He then completed a Master's degree in Imaging Science from RIT in 2021. His research with Dr. Jan van Aardt applies multiple imaging modalities to improve precision agriculture and forest inventory practices.

Graduate Students: PhD Candidates

Dickinson, Thomas (Will)

Murphy, Matthew

Kirkendall, Jason

Liu, James J

Mao, Davin

Figlewski, Nathan Michael

Wible, Robert

Lee, Chris H.

Mcghee, Drew

Nur, Nayma

Denton, Jonathan

van Cor, Jared

Jahan, Nusrat

Khata, Elphas

Conran, David N

Liu, Xuesong

Walia, Tanya

Cañas, Chase

Mogere, Nyaburi

Bajracharya, Binyul

Bergstrom, Austin C

Cao, Grace

Macalintal, Jose

Connal, Ryan

Lekhak, Sagar

Poudel, Nakul

Bhatta, Ramesh

Chaity, Manisha Das

Patki, Kedar Sanjay

Saif, Mohammad

Siddiqui, Tahrir

Levental, Yuval Haim

Ashrafee, Alif

Nusbickel, Zach

Graduate Students: MS Candidates

Flack, Dominic

Donnelly, Kevin

Aktas, Tolga Furkan

Maloney, Colin John Henry

Cao, Ting

Dougherty, Jake

Krishnamurthy, Abhiskek

Kumaran, Karthick

Undergraduate Students

Ross, Micah

Rafferty, Jacob

Burton, Brandon

Sutkus, Evelyn

Kachmaryk, Grace

Mancini, Bobby

Klosinski, Danny

Talapenari, Deepak

Ho, Aries

Secular, Christian

Spinosa, Luke

Publications

The following publications are from our hardworking staff members and required hours of dedication and commitment.

Publications

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